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BUILDING DESIGN ASPECTS AND BLAST LOAD DETERMINATION AGAINST TERRORIST ATTACK AS A REVIEW

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Abstract— Terrorism is the paramount enigma of the world. Many countries are affecting politically and financially through explosion attacks. The explosions by terrorists are accidental produce` extreme and impulsive loading on structures, and it creates a considerable loss of occupants, bystanders, and property. The main aim of explosion attacks is to create a crisis through assassinating people in opened and closed places. The closed areas refer to buildings, where security measures are low to medium, and possibilities of blast event planning accomplished. In this scenario, worldwide, the blast resisting structures design practicing and implementation is most necessary for traditional buildings and mandatory for national security issue based buildings after September 11, 2001 attacks. The objective of this paper is to crystallize blast resisting design in architectural and structural points of view by impending some fundamental changes and additional features to the standard plan of a building. The behavior of the structure is abnormal when the blast occurs depending on the magnitude and location of the explosion takes place. To minimize the loss due to blast providing the steel jacketing is one of the best techniques to follow for a strengthening of columns and beams. Also, a reduced number of opening for windows, doors, and aesthetic glazing and cladding helps to increase safety against bomb attacks. The structural shape management, bomb shelter room arrangement is an excellent strategic approach to escape from the intensity of the blast effect. Finally, the determination of blast loading on the building helps to give the structural design arrangement and architectural planning layout approach.

Index Terms— Blast Resistant, Blast Effects, Blast Waves, Blast Loading

1 INTRODUCTION

Terrorism, in the broad sense, is intentional violence primarily to refer to violence during peacetime or war context against mostly civilians. The word terrorist and terrorism started during the French revolution in the 18th century and came into limelight in the 1970s during conflicts of Northern Ireland, Palestine, and the Basque country. According to the Global Terrorism Index 2016 (Measuring the Impact of Terrorism), the India and Ethiopia Index placed within the rank of 100[5]. From the last few years, the increase in the number of terrorist attacks has shown the effects of blast loads on building structures. The structural designers nowadays facing new challenges and coming up with require methods and guidelines on how to design structures to resist various antagonistic acts. The arrangements with fully blast resistance are not an economical and realistic option. However, enhanced knowledge in engineering and architecture mitigates the effects of the explosion on the new and existing building.

The main focus of this paper is to guide to mitigate the threat of terrorist attacks by explosives like TNT or RDX on civil buildings, therefore prevailing human protection, structure, and valuable appliances. The paper suggests information about explosives, blast loading parameters, and physical security measures need to balance with other design requirements against fire protection, energy efficiency, accessibility, and aesthetics. It requires a complex series of tradeoffs. The primary objective of terrorist attack resistant building is to save the lives as well as damage limiting and damage mitigation. Terrorist attack resistant structure can achieve by providing some reasonable measures to enhance the safety of the human presence inside the building and also facilitate rescue efforts in the event of a blast attack. The effects of terrorist attacks will be catastrophic. Still, the security measures should not interfere with the daily operations of the building, because the probability of blast attack against a particular building is small. The structural designer should accomplish the preventing of the catastrophic collapse of the building to reduce the loss of life of the occupants and also structural debris. The flying debris and air blast pressure of an explosion will create more damage to the occupants when such an event has occurred. Condensed explosives which are in solid form causes high chemical reactions by its detonation considered in this study. The explosions categorized under three types: a) Unconfined Explosions b) Confined Explosion c) Explosions caused by attached to the structure[1]. The structure burst or airbursts are known as unconfined explosions in which the detonation of high explosives occurs above the ground level, and intermediate amplification of wave caused by ground reflections occurs before the arrival of initial blast wave at a building as shown in figure1.

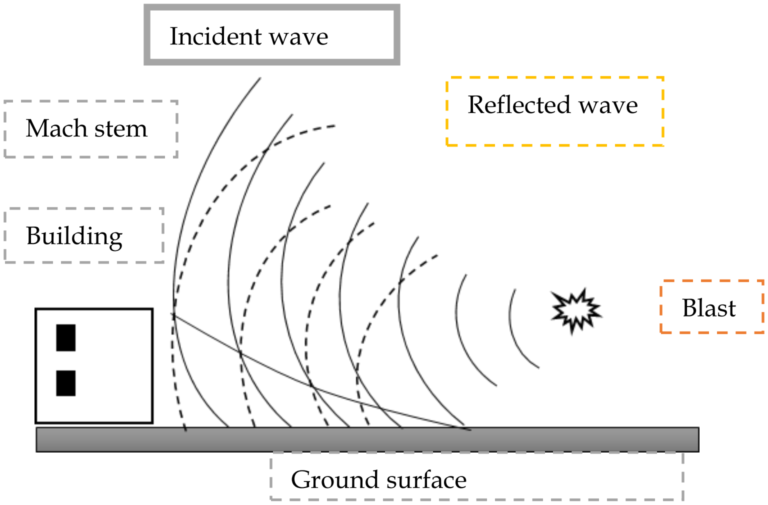


Fig. (1) Airburst with the ground reflection

And the Mach stem is formed by the interaction of the initial onslaught and the reflected wave. As well as in surface burst, the determination of explosive occurs close to or on the ground surface. The process of reflection and amplification of initial shock waves by the ground surface will produce reflected waves as shown in figure2

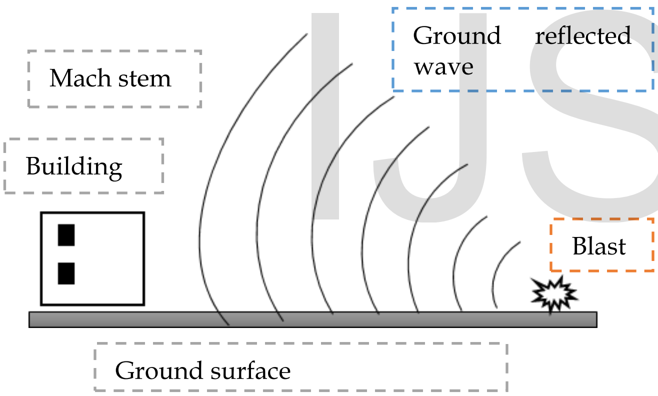
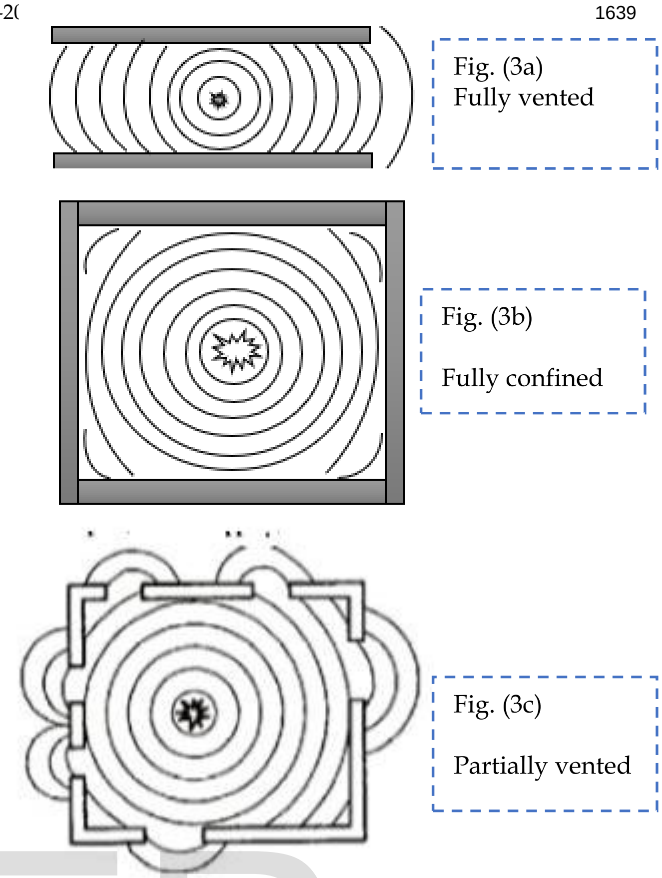


Fig. (2) Surface burst

If the blast occurs within a building, the initial shock waves and the high pressures/ energy released due to burst will amplify by the reflections with the building. It is known as the confined explosion. Depending on the degree of confinement, the effects of the released gases and high temperatures evolved by the chemical reaction will cause additional pressures and load duration within the structure[9]. Based on the extent of opening, confined explosions are categorized into fully vented, partially vented, and fully enclosed, as shown in figure3(a),3(b), and (3c)[1].



Lastly, if the detonation of an explosive occurs by contacts of structural components like beams, columns, and walls, etc. the blast event will liberate intensified waves in the contact material, which leads to the material crushing and makes the building vulnerable to collapse. These are many types of high explosives available that have their detonation characteristics. RDX considered as atomic charge mass for the discussion.

2 Explosion Process

An explosion is the rapid release of stored energy. When the blast event occurs, gas, liquid, or solid material will go through a swift chemical reaction. Due to biochemical reactions by blast event liberates high temperatures and pressures into the surrounding areas through blast waves; The damage caused by the blast produced by the passage of compressed air in the blast wave.

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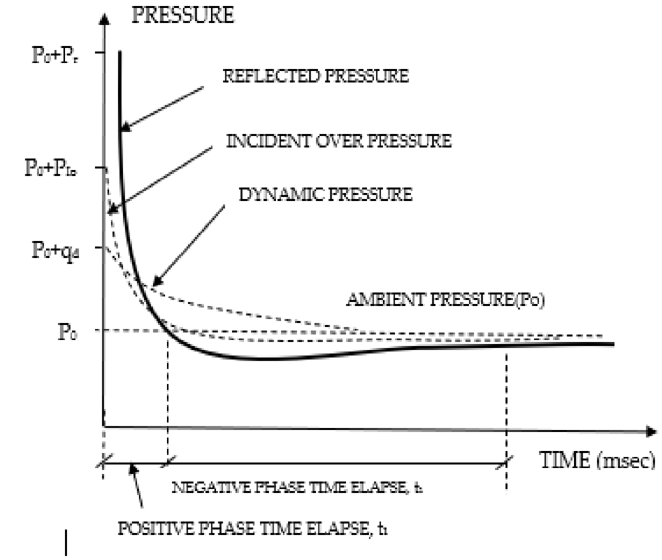

Fig.(3d) Air burst pressure time elapsed graph with blast wave properties

The high blast will typically have high shock value with zero rise time[8].

These blast waves propagated at supersonic speeds and reflected as they meet objects. The blast waves diminish its intensity and effects when it expands away from the source. These blast waves will travel with very little strength when it passes in confined /enclosed passages. At the place of explosion event, the blast waves produce the hot and intense pressures due to the rapid release of energy, which exerts more loads and difficult to quantify precisely. Once the blast wave has termed and propagating away from the source, it is convenient to separate the different types of loading experienced by the surrounding objects[6] shown by fig. (3d).

2 METHODOLOGY

2.1 ARCHITECTURAL DESIGN ASPECTS

The main objective of terrorist attack resistant building philosophy is limiting the damages caused by humans and buildings. The prime requirement to limit the damage is controlling the catastrophic failures. In response to a significant/potential threat of terrorist attacks, particularly after the incident of September 11, 2001, most of the private and public sectors are increasingly interested in following terrorist attack resistant structures design techniques in their constructions. The basic level of any structure starts with an architectural plan layout focusing on the essential plan stage by the implementation of design aspects of the structures that can design as terrorist attack resistance. However, sometimes blast resistant building design methods will conflict with aesthetical, fire safety, accessibility variations, and also the economics of building. The following are some of the design aspects from the architectural point of view.

2.1.1 LAYOUT PLAN

The maximum reduction of explosion threats and associated risks and mitigation of structures can be achieved at the planning stage, as we discussed. To protect the building from blast attacks, either structural or non-structural members adequate placing of shelter areas within a building should be provided. The safety distance between the object and threat called standoff distance; its a crucial security measure that considered in designing of layout plan in the view of external threats. By providing the strategic safety standoff distances from the outer wall to the building, it minimizes the effects of blast wave propagations into the building in case of external bomb threats, so that the fragility chances to the building reduce. Maximum the standoff distances ensure to minimize the damage of structures. Sometimes this may not be achieved in congested places or streets, but whatever possible safety distances are prevailing have to consider in the design of plan layouts. The exclusive standoff zone provides a higher level of protection as per the U.S Department of defense, the recommended minimum standoff distance for original buildings is 25m away from parking and roadways without a controlled perimeter and 10m away under controlled edge (UFC-4-010-01, 2002) Figure 4[2].

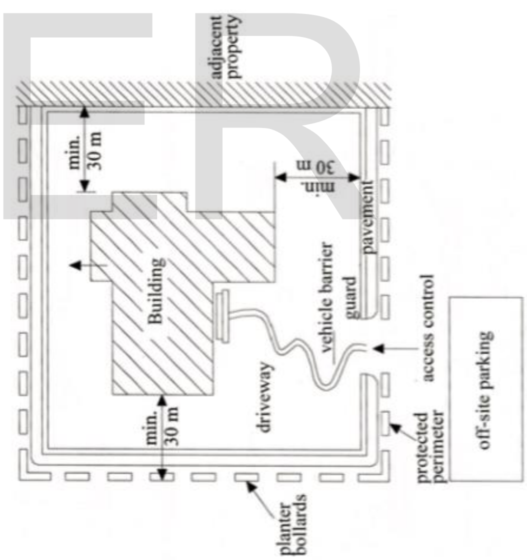

Fig.(4) Planning layout of building area for protection against blasts

2.1.2 PROTECTIVE BARRIERS

Providing protective barriers is one of the best methods for anti-terrorist attack buildings. These protective barriers are fixed or movable, which is enclosed to the standoff zone, as shown in above figure4. The set barriers are in a continuous ready state all the time along the perimeter of the standoff zone. Whereas mobile walls are automated, which can be used for safety and also controlling the parking around the building. Generally, planters and bollards used as protection barriers, which are reinforced concrete for reliable and robust metal for movable. The kinetic energy resistance measures the capacity of a barrier. The planters and bollards used, height should be as high as vehicle bumper.

2.1.3 SHAPES OF STRUCTURES

As much as possible for the design, Arches and domes shapes for the structure will reduce the blast effect substantially rather than regular corner shaped buildings. Structural shapes significantly affect the blast loads acting on them. The blast waves cause multiple reflections due to the more complex forms of ways; that is why aesthetics are conflicts by safety in blast-resistant buildings. Unnecessary structural projections or cantilevers and U-shaped plans are unsuitable for the protection of the building. The multistoried buildings are less resistant than single storied building when the blast event occurs. The internal plan layout is another important parameter that should be considered for isolation of threat from inside of the building, whereas barriers and standoff distances controlled the external threat. Reinforced concrete walls protected Foyer areas and eccentrical double dooring systems for rooms and robust construction for lobbies avoiding underground car parking or underpass; these are the necessary arrangements that considered for the internal plan layout of the building. Providing automatic firer breakers, alarms within a structure may increase the safety of inhabitants to avail the bomb shelter rooms in the event of potential threats.

2.1.5 BOMB SHELTER ROOMS

These bomb shelter rooms are specifically designated and located within the building at the place where the effects of the blast are minimum and act as a hideout room for inhabitants in the event of bomb warning. More safety for more inhabitants, these rooms designed with ample space and easy access with reasonable protection against threats. These shelter rooms specially designed with proper communication facility to out, sufficient sanitation and ventilation, and acoustic insulation to less than eardrum rupture pressure in the event of the blast also alternative means of escape from the room. The bomb shelter rooms are highly essential to design aspects of the terrorist attack resistant building so that the full measures considered while locating in the internal plan layout. These rooms kept away from external walls, doors, windows, aesthetic view openings, weak corners top floors, and underground parking where there is a vulnerable to damage by the threat.

2.1.6 GLASS CLADDING

The cladding is a covering or coating on a structure with glass material. Glass cladding used for doors, windows to achieve good aesthetics for the elevation of buildings. At the same time, the broken and shattered glass windows or doors could be responsible for numerous injuries in the event of blast threat. Instead of regular glazing, TTG laminated glass usage is a compelling idea. The minimum of glazing in the façade is the maximum of safety against injuries for the inhabitants.

2.1.7 FITTINGS OR FIXTURES

The internal fittings are very crucial points to be considered and should be high-risk deformation free. The fixtures like electric connections, water connections, elevated tanks, gas, and stream installations fixed, such that should have less vulnerability in the event of blast occurs. The control units, feeding points should be covered from direct attacks. Also, a reserve system for control units maintained in the chance of explosions. Avoid the fittings arrangements in sensible areas like lobbies and parking places, slabs, and external walls, unless if they effectively controlled.

2.2 STRUCTURAL DESIGN ASPECTS

Structural safety is an essential aspect of the design of terrorist attack resistant buildings. The main structural components like columns, transfer Girders or beams, floor slabs, façade and atrium, shear wall, exterior lower floors, and Non-structural elements like glazing for windows, etc. are should be designed with blast-resistant features. Due to external blast events, waves will reflect, amplify, and effect the front elevation of the building with a peak overpressure. The rear side of the structure experiences no pressure until the blast wave has traveled the length of the structure, and a compression wave has begun to move towards the center of the rear face. Therefore the pressure built up is not instantaneous.

The blast loadings effect should be taken into consideration for structural design by an adequate ratio. Limit state design methods used for dynamic blast loads, which are similar to the static load design. The plan of fundamental design aspects as per the serviceability limit state requires the building to continue functionality after a potential blast event occurs, except the non-structural members like windows, doors, and cladding.

2.2.1 COLUMNS

The lower floor columns must be designed with adequate elasticity and strength to withstand the blast loading pressure. The perimeter of the column must give due importance designed to resist extreme blast effect supporting to lower floors. It can achieve by a straightforward technique called Steel Jacketing. The encasing of steel jacketing to column perimeter will provide potential confinement increase in shear capacity, strength, and elasticity. Core confinement will attain the columns providing spiral reinforcement, which improves the ability of loading.

2.2.2 TRANSFER GIRDERS OR BEAMS

The large dimension beams termed as girders—the column-free architectural space ensured by the transfer girders, particularly at the building entrances. Designing transfer girders typically concentrate load transfer system, which runs contrary to the redundancy concept in a blast event. The transfer girder and column connections designed and appropriately detailed because it should provide continued strength despite inelastic determination.

2.2.3 FLOOR SLABS

In the designing of slabs, more attention should pay for exterior bays and lower floors. The floor slabs designed with drop panels, column capitals will shorten the sufficient slab length and increase punching shear resistance. The shear heads embedded in the Slab to a column when facing the challenges vertical clearance. Bottom reinforcement should be continuous through the column. Closed hoop stirrups should be designed

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for slab column interface to increase the load-bearing capacity at blast events.

2.2.4 FLOOR SLABS

The ability to resist high impulsive loading for a building depends on the elasticity of the load resisting system. For a well-distributed lateral load resisting mechanism design more number of shear walls around the plan of the building will ensure the blast resistance to the structure. Even though designing more shear walls are not architecturally feasible, a combined lateral load resisting mechanism can also be adopted. Providing Central shear walls are perimeter moment-resisting frames that will ensure a balanced solution.

2.2.5 FAÇADE AND ATRIUM

As we already discussed in architectural design aspects, usage of glazing for the elevation of buildings should be limited. Use TTG for the façade of the building. The presence of atrium along the face of the building requires two essential measures for outsides of the structural glass and glass frames strengthened by using good quality hard materials. Inside of structure like balcony parapets, exposed slabs, spandrel beams must be strengthened.

2.2.6 EXTERIOR LOWER FLOORS

The exterior lower floors must be designed with reinforced concrete to avoid severe damage when a blast occurs. The reinforced concrete walls with a nominal thickness of 300mm with 0.3% reinforcement intended to protect small charge blast loadings. For a standard charge of blasts, a 460mm thick wall with 0.5% of steel reinforcement recommended.

2.2.7 INTERNAL EXPLOSION THREATS

The concept of internal explosion threat will be directly related to the structural design aspects of the building. Generally, if a blast event occurs, four vulnerable locations will be affected. The entrance lobby, basement room, loading dock, and first rooms are the most sensitive spaces. It should need strengthening. All vulnerable areas must be hardened by redesigning of slabs and erecting cast in place shear walls to protect against internal explosion threat through hand-delivered package bombs. The basement should be isolated similarly.

3 DETERMINATION OF BLAST LOADS

3.1 BLAST LOADS

The prime importance of structural design to resist blast event and progressive collapse is finding its nature and magnitude of the blast. The type of explosive is also an essential factor for designing of blast loads. The different blast materials have different intensities when the blast occurs. The blast threat maybe a hand-delivered bomb or suitcase bomb or vehicle attached bomb or some other means of arrangement. Some types of blast materials are challenging to obtain. Some are easy.

The illustration of blast load determination has done with the following data.

The overall blast effect depends on charge weight W, measured in an equivalent weight of RDX, the standoff distance R, The peak pressure is a function of distance R divided by the cube root of the charge weight W. This is commonly called and expressed as Scaled Distance = $R/W^{1/3}$. Another way of viewing scaled distance and pressure relationship is by Peak Pressure - W / R^3.

3.2 DETERMINATION OF BLAST LOAD

An explosive device consists of 175kg RDX. It located in a composition city road street 10meters from a target G+4 building. This blast load shall be assessed in application to a double glazed unit 1.75m wide by 2.25m high with its center 8m above the ground. The peak reflected overpressure and reflected impulse for a point of interest on the front elevation of the building, as shown in figure 5.

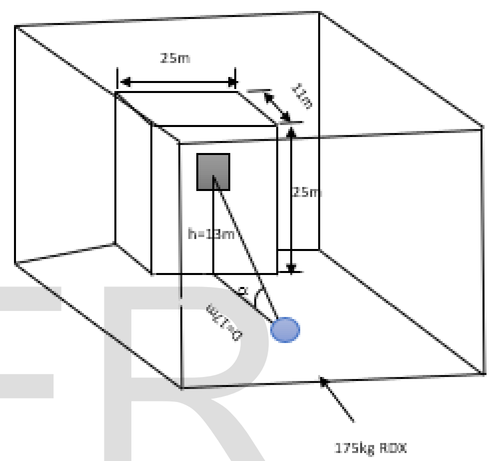

Fig.(5) Geometrical building block in 3-D

STEP1: Charge weight W= 175kg of RDX with semi-spiral charge height h=13m, and D=17m.

STEP2: For the point of interest $D_h = \sqrt{(13^2+17^2)} = 21.4$m

$D_s = D_h/W^{1/3}$ where,

D_s= Scaled distance
D_h = Standoff distance
W= Charge weight

$D_s = 21.4/(175)^{1/3}$ 3.8259 m/kg$^{1/3}$ >D_{min}= 1.2 m/kg$^{1/3}$
α = Angle of incidence
= $\tan^{-1}(h/D) = \tan^{-1}(13/17)$
= 37.4°<45°

STEP3: Finding of reflected blast wave parameters for Ds= 3.8259 m/kg$^{1/3}$ from TMS-1300 U.S. Army, 1991.

P_r =149 kpa
$i_r/W^{1/3}$ = 715/175 kpa-msec
= 4.0857 kpa-msec/kg $^{1/3}$
$t_o/W^{1/3}$= 18.7/175 msec/kg $^{1/3}$
= 0.168571 msec/kg $^{1/3}$

If the peak load on a glazing unit required for design purpose, the panel load calculated as:

Load = 146 kpa*1.75m*2.25
= 574.875 Kn
Impulse = 715 kpa-msec*(1.75m*2.25m)
= 2815.3125 kN-msec.

4 CONCLUSIONS

This paper initiates essential concepts that are helpful to practice the terrorist attacks resistant strategies to structural design engineers and architects for the new and existing buildings—the in-depth defense strategy to flow when the blast occurs to avoid the series damage to man and material. Also, mitigating from the event of a blast, for example, bollards, barriers, and less opened features of the building, prevent the progressive collapse of the structure and the adjacent. Based on prior planning and implementation of their design concepts also by adding available low-cost materials to enhance the building safety, security, and mitigation of structure wangle.

5 REFERENCES

[1] Yandzio, E., Gough, M. (1999). Protection of Buildings Against Explosions, SCI Publication, Berkshire, U.K.
[2] Smith P.D., Hetherington J.G. (1994) Blast and ballistic loading of structures. Butterworth Heinemann.
[3] Zeynep Koccaz, Fatih Sutcu, and Necdet Torunbalci, October 12-17, 2008The 14th World Conference on Earthquake Engineering Beijing, China
[4] TM 5-1300 Structures To Resist The Effects Of Accidental Explosions, U.S. Army Corps of Engineer
[5] Global Terrorism Index 2016
[6] Hill J.A., Courtney M.A. (1995). The structural Engineer's Response to Explosion Damage. The Institution of Structural Engineer's Report, SETO Ltd, London.
[7] UFC-4-010-01, (2002) Department of Defence, Unified Facilities Criteria – DoD Minimum anti-terrorism standards for buildings.
[8] Alexander Remennikov University of Wollongong, alexrem@uow.edu.au D. Carolan Taylor Thomson Whitting Consulting Engineers, NSW, Building vulnerability design against terrorist attacks,2005
[9] https://vdocuments.net/report-on-blast-resistant-building.html