Blast Assessment – A Methodology

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1. Introduction

The deployment of the first troops a new Area of Operations following a conflict, creates a significant logistical problem, and the lack of adequate infrastructure for the settlement of these forces leads, sometimes, to use existing infrastructure for operational purposes. The need to protect the military servicemen, in face of plausible improvised explosive device threats is of utmost importance. This brings the need to assess the extent of the expected damage and to evaluate the level of threat as well the protection standard needed.

2. The problem to be adressed

Recent experimental research projects and studies [1] developed at the Centre of Competencies for Infrastructure Protection of the Portuguese Army allowed, among other findings, to realize that:

a. In an exterior burst, the action is primarily local (e.g. in a column) and can turn into a global collapse (progressive collapse);
b. The façade cladding elements (masonry, window frames, panel claddings) exhibit a much lower resistance than the supporting elements, resulting in their collapse before there are more serious consequences on the supporting structure;
c. The throw of fragments of façade elements can be lethal, and need to be controlled.

It is therefore important to develop protective systems and measures to address essentially the following problems:

a. Protect the structural elements directly exposed to the explosion;
b. Control the throw of fragments of brittle elements;
c. Increase the capacity of the structure or system to retain fragments or projectiles for occupant protection;

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d. Develop solutions of structural strengthening oriented to the increase of resistance and robustness of the structures against the explosion effects, ensuring that, failing protection, the structure does not collapse.

3. Assess the suitability of structures to operational purposes

The present paper proposes an approach to blast assessment, using the sequence shown in figure 1 and detailed in the following sections.

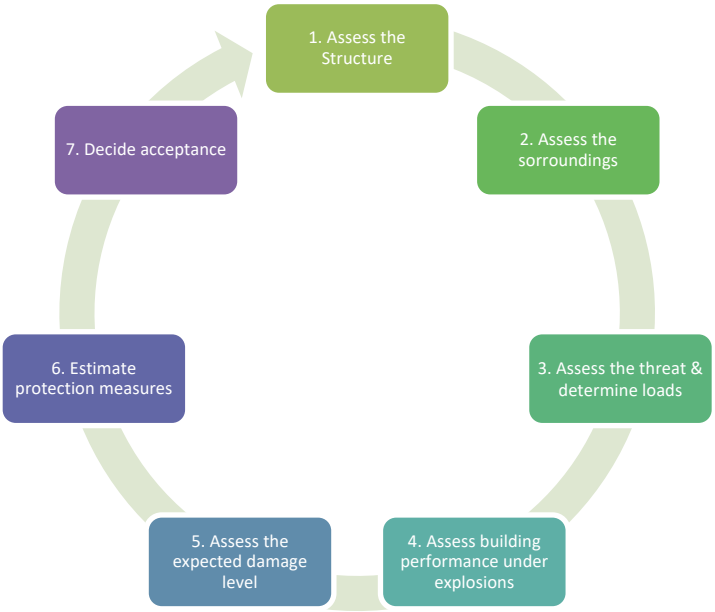
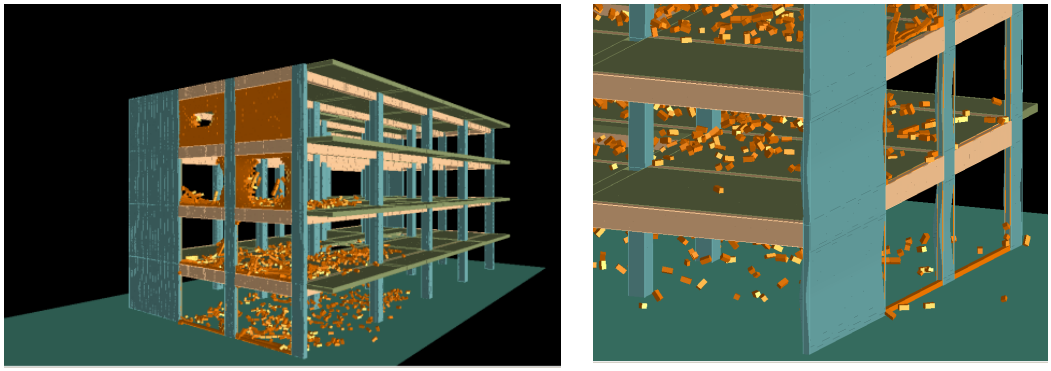


Figure 1 – Proposal of blast assessment cycle [authors]

a. Structural assessment

The analysis techniques and data collection in structures are well documented in extensive literature and international standards [2].

The most vulnerable components of a building are those exposed to the explosion, due to the consequences that can affect the global stability and injuries to occupants.



(a) (b)

Figure 2 – Simulation of the effects of a 250Kg charge ; (a) overall damage; (b) detail of the deflections in walls and columns [authors]

Thus, besides the local and global robustness, it is desirable that the structure has rigid cores that allow the establishment of shelter areas inside buildings. In the same way, buildings with large areas of glazing should be avoided to minimize injuries resulting from the throw of glazing fragments [3];

b. Evaluation of the sorroundings

The possibility of taking advantage of the terrain to increase protection is essential for the study to be developed. Thus, the orientation of buildings, their relationship with traffic routes, the existence of natural barriers such as water, vegetation and slopes, the possibility of establishing physical barriers that guarantee a minimum safety distance, the location of parking spaces, are relevant aspects.

c. Assess the threat and determine loads

In a military context, the threat assessment should cover the plausible explosion scenarios, in particular the location and size of the explosion [4]. The calculation parameters are determined by the basic shockwave characteristics [5, 6] as shown in the curve of figure 3.

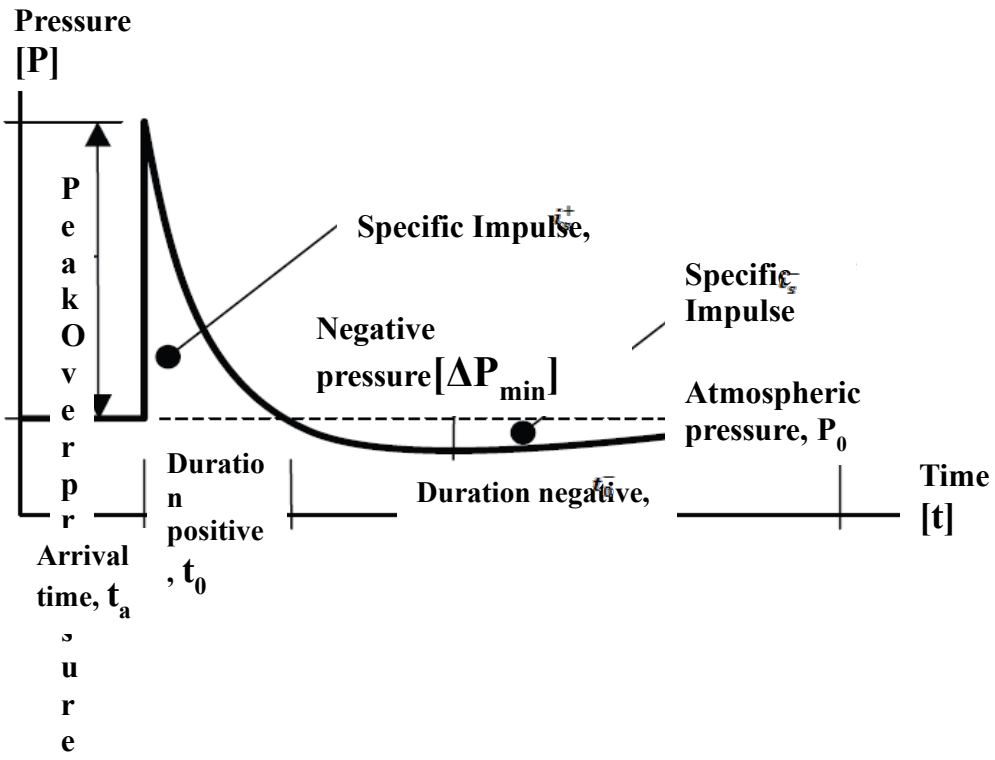
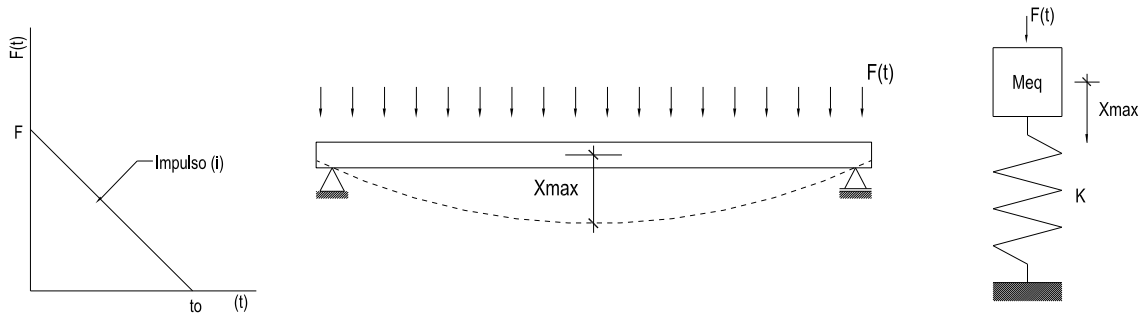


Figura 3 – Shockwave profile [5,6]

d. Assess the building performance under explosions

The preliminary evaluation of the resistance of the building can be done by separating the complex three-dimensional system into subsystems (Figure 4). In this way, a structure can be evaluated by the successive analysis of its parts with simple analytical models.



(a) (b) (c)

Figura 4– Equivalent undamped model for dynamic analysis. (a) Equivalent triangular pressure diagram; (b) beam subjected to uniform loading of magnitude *F(t);* (c) Equivalent oscillator with one degree of freedom. Adapted from [7,8,9]

Thus, the analysis should focus on the structural elements which are both more exposed to the explosion (exterior) and contribute to support the building.

e. Assess the expected damage level

The acceptable response of the structure is usually controlled by limiting deformations for each required level of protection, which represents the degree of acceptability of the occurrence of damage or injuries to persons or equipment in the event of an explosion [8,9].

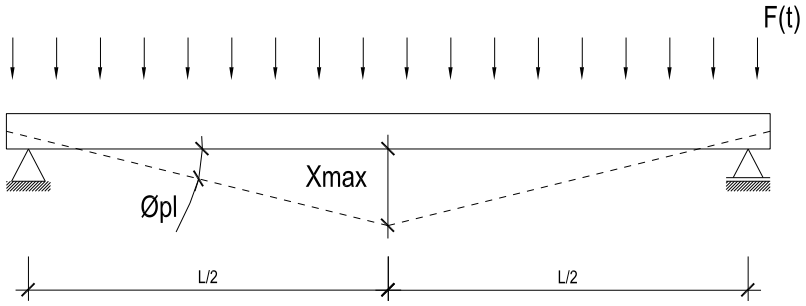


Figure 5 – Limitation of the rotations ate the supports as control measure

Hence the imperative need to correctly identifying the type of use expected for each part of the infrastructure, taking into consideration the location of human activities in areas more protected from the direct effects of an explosion, leaving to unfavourable locations to activities and non-critical equipment or materials.

f. Estimation of protection measures

Infrastructure protection should not be seen as an absolute concept, and the optimal point between the cost of protection and the cost of potential losses should be determined, avoiding a waste of resources [11]. This criterion can be satisfied by balancing the maximum available distance to a threat and the engineering measures related to the master plan or to the strengthening of the infrastructure (masonry, frames, cladding, etc.).

4. Conclusions

Assessing existing infrastructures against the effects of explosions is an essential process when the threat is considered relevant. This evaluation can be done through

analytical methods because they are relatively reliable, but require some engineering judgment.

The impossibility or inadequacy of the engineering measures, considering the level of protection that is intended to provide and the residual risk to be accepted, will allow reaching the decision to reject an infrastructure for occupation or to develop a certain type of activity.

References

[1] Gomes. G, (2016). Reutilização de edifícios para fins operacionais – Blast Assessment. Instituto Universitário Militar. Lisboa

[2] ESA. (2012). Bases for Design of Structures - Assessment of Existing Structures (Identical with ISO 13822:2010). Ethiopian Standards Agency.

[3] DoD (2008). UFC-4-20-01 – Security Engineering Facilities Planning Manual. US Department of Defense.

[4] NATO. (2016). ATP-3.12.1.8 - TEST PROCEDURES AND CLASSIFICATION OF THE EFFECTS OF WEAPONS ON STRUCTURES, Edition A, Version 1. Brussels: NATO STANDARDIZATION OFFICE (NSO).

[5] UFC 3-340-02. (2014). Structures to Resist the Effects of Accidental Explosions. Retrieved março 21, 2015, from Whole Building Design Guide web site: http://www.wbdg.org/ccb/DOD/UFC/ufc_3_340_02.pdf

[6] Kinney, Graham. (1985). Explosive Shocks in Air, 2nd edition. Springer Berlin Heidelberg.

[7] USACE. (2008a). PDC TR-06-01, rev 1, Methodology Manual for the single-degree-of-freedom blast effects design spreadsheets (SBEDS). US: Protective Design Center.

[8] ASCE. (2012). Design of blast resistant building in petrochemical facilities. US: American Society of Civil Engineers.

[9] ASCE. (2011). Blast protection of buildings, ASCE-SEI 59-11, American Society of Civil Engineers.

[10] USACE. (2008b). PDC TR-06-08, rev 1, Single degree of freedom structural response limits for antiterrorism design. Ohama, Nebraska: Protective Design Center.

[11] Cormie et al. (2009). Blast Effects on Buildings, 2nd edition, London: Thomas Telford.