# MYTH OR FACT: IS THERE A LINK BETWEEN WAVELENGTH AND BARRIER MITIGATION FACTORS?

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ABSTRACT
In this work, we focus on the third item: the use of obstacles to mitigate the effects of an explosion. The aim of the study is to precisely characterize the interaction of an explosive blast wave with an obstacle used as a barrier. The obstacle is considered as non-deformable. In particular, the effect of the shape of the obstacle on the blast wave propagation and maximum overpressure is investigated through the notion of wavelength. To achieve this, various shapes of rigid reduced-scale obstacles were exposed to overpressure waves generated by different types of blast sources: parallelepipedic, cylindrical and hemicylindrical reference shapes and a straight wall. This innovative approach will contribute to proposing guidelines on geometrical and physical dimensioning of protection barriers so as to improve the efficiency of protective means in terms of blast effects mitigation.
*Keywords: blast, explosion, mitigation, barrier, security and safety, innovative methodology.*

## 1 INTRODUCTION

Nowadays, security of personnel and goods is of major interest. In order to improve the level of security of civilian, industrial or military infrastructures, it is necessary to predict blast effects consecutive to the effects of a strong explosion (accidental or malevolent) in a complex environment. In general, these effects can be suppressed or at least mitigated by means of:

- inhibition of blast source (chemically, physically, …),
- confinement of blast source (porous material, water, …),
- use of obstacle disrupting the blast propagation in the vicinity of a target,
- addition of a protective layer at the target surface,
- requirements in terms of stand-off distances.

## 2 BLAST INTERACTION WITH OBSTACLES

The following various shapes of rigid reduced-scale obstacles were exposed to overpressure waves generated by different types of sources (Fig. 1): parallelepipedic, cylindrical and hemicylindrical, straight wall.

Several previous studies investigated the use of rigid mock-ups facing explosive charges at small scale as a way to characterize their mechanical load (i.e. evolution of overpressure at their surface), as for example, Lapébie et al. [1]. An alternative technique consists in placing mock-ups directly inside a shock tube. This setup is particularly adapted to reproduce and visualize steady planar shock waves, representative of far-range blast. However, most shock tube setups are unable to reproduce a spherical divergent blast wave (tri-dimensional), representing a close-range explosive event.

In Trélat [2], the transmission coefficient ($C_t$ in Fig. 2) determined for a specific point at the surface or downstream of an obstacle and for a physical characteristic (peak overpressure, arrival time, impulse, positive phase duration, etc.), is defined as the ratio between this

WIT Transactions on The Built Environment, Vol 215, © 2025 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/SUSI250211

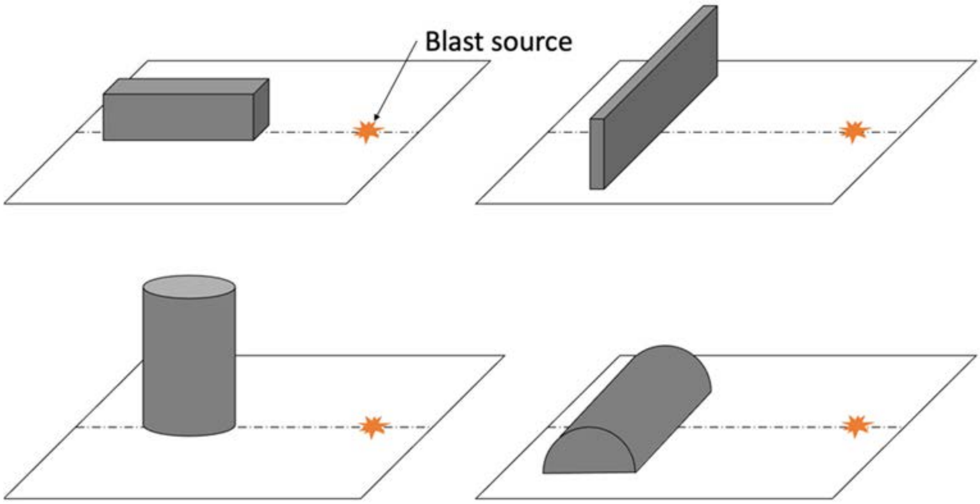


Figure 1: Examples of reference reduced-scale mock-ups exposed to a blast wave.

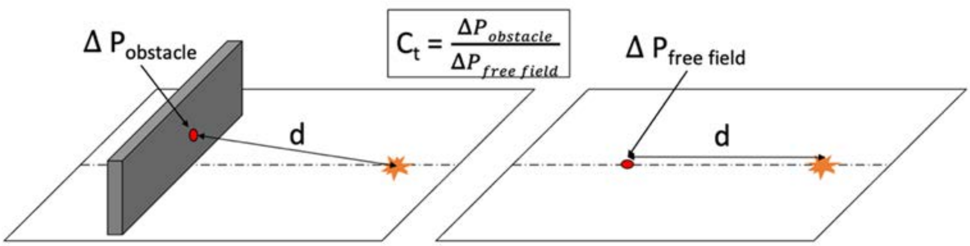


Figure 2: Transmission coefficient $C_t$ at an obstacle surface point exposed to a blast wave, at a distance d from the source. Example with overpressure parameter (ΔP).

characteristic value and the value that would be obtained at the same distance in free field. Concerning peak overpressures, this ratio is commonly denominated as reflection coefficient for a surface point directly exposed to blast.

Overpressures on different obstacle surfaces collected from our work quantify the ability of the structure shape to alter (increase or decrease) the wave intensity by their deviation to the values in free field at equivalent distances.

## 3 BLAST WAVE LENGTH

Blast wave length and specific length are, respectively, defined by the product of the positive phase duration with the speed of sound in air and the local blast wave speed at a specific time of the wave propagation. These parameters (acting as scale factors for free field detonation) were useful to interpret local levels of amplification or attenuation around obstacles, once they were divided by a characteristic length depending on the obstacle geometry (radius, height, width, etc.) and the relative position to the point of interest. Such ratios are usually defined to evaluate the average blast load on an exposed obstacle surface.

Fig. 3 aggregates evolutions of transmission coefficient Ct measured in the wake of three barrier shapes (cylindrical in red, parallelepipedic in green, pyramidal in blue) extracted from different studies (dealing with detonation and deflagration propagation regimes) as a function of a dimensionless ratio LoS+/L (where LoS+ represents the specific wave length at the beginning of the expansion phase and L the direct distance 'deployed' from this point to the point of interest, see Fig. 4). The considered reactive sources and propagation regime couples are the following (and also summarized in Table 1):

- Trélat [3] detonated gaseous $C_3H_6/O_2$ volumes next to cylindrical shapes,
- IRSN and ISL conducted a joint work [4] on blast generated by Hexomax charges, propagating in front of hemicylinders placed on a blast table and blast pad surface,
- Trélat et al. [5] reported the blast loading characteristics on parallelepipedic obstacles resulting from the detonation of a stoichiometric $C_3H_6/O_2$ mixture,
- INERIS [6] designed an experimental campaign to investigate the effect of deflagrating gaseous charges ($H_2/O_2/N_2$ mixture) in the vicinity of concrete L-wall segments,
- Vyazmina et al. [7] proposed a numerical study to assess the protective characteristics of walls from the effects of a vapor cloud explosion,
- Pellegrinelli [8] exposed a straight merlon to the blast effects from gaseous H2/Air deflagrations,
- Triangular section barricades were studied by Allain with exposure to TNT detonating charges,
- Eveillard [10] detonated gaseous $C_3H_6/O_2$ charges in front of a similarly shaped merlon,
- INERIS [11], [12], respectively, exposed reduced and large-scale walls to the pressure effects of deflagrating $H_2/O_2/N_2$ mixtures,
- For [13], a large-scale wall was placed in front of a 50L shock wave generator containing a deflagrating $C_2H_4/O_2$ reactive composition.

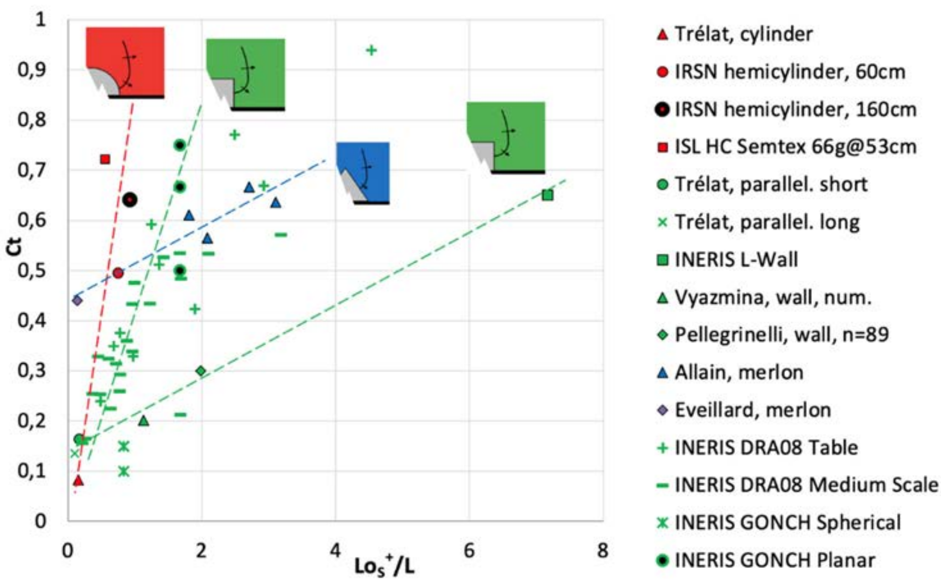


Figure 3: Evolution of transmission coefficient of $C_t$ as a function of $Lo_S^+/L$ and the obstacle shape.

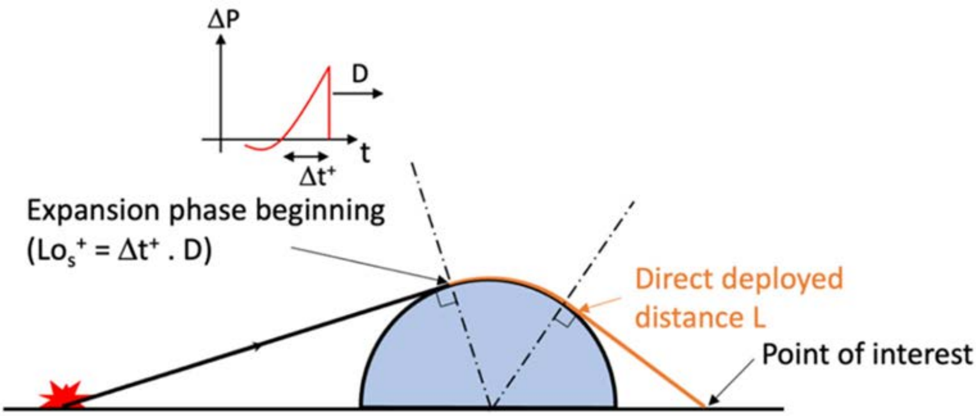


Figure 4: Illustration of beginning of expansion phase and direct deployed distance L (D: shock wave velocity in m/s, Δt+: positive phase duration in s).

This representation links transmission coefficients estimated downstream of the various shapes obstacles to a dimensionless parameter based on obstacle and source physical characteristics.

The influence of wave length on the attenuation ability of an obstacle exposed to a blast wave (generated either by detonation or deflagration combustion regimes) will require further studies in the future: a concrete parallelepipedic barrier will be placed in the vicinity of various exploding sources to investigate its attenuation factor on blast propagation, depending on the explosion intensity.

We have to keep in mind that the positive phase of deflagration waves is generally of longer duration and of different temporal evolution than for detonation phenomena. We can thus expect that effects on a large target may strongly differ with the various reactive regimes, for a similar peak overpressure level for instance. Geng and Thomas [14] already illustrated that for the same peak overpressure: attenuation behind parallelepipedic obstacle decreased with the wave length increase.

## 4 CONCLUSION

Effects of blast wave propagating around obstacles were investigated by studying the transmission coefficient for peak overpressure, i.e. the attenuation factor due the presence of the obstacle impacted by the blast. The influence of the wave and the obstacle physical characteristics were taken into account through the ratio between the specific wavelength and the deployed propagation distance.

Results showed that depending on the type and shape of barrier, correlations can be observed. In order to confirm these links, further investigations will require to vary the scale of the targets for similar types of explosive sources and also to explore other types of blast profiles generated, for example, by gaseous deflagration waves.

Table 1: Reactive sources and propagation regime couples.

| **Obstacle shape** | **Reactive source and propagation regime** | **Obstacle dimensions** |
|---|---|---|
| Trélat vertical cylinder [3] | Gaseous detonation | Diameter 0.36 m<br>Height 0.36 m |
| Trélat hemicylinder [4] | Hexomax detonation | Diameter 0.40 m<br>Length 1.60 m |
| IRSN hemicylinder [4] | Hexomax detonation | Diameter 0.40 m<br>Length 1.60 m |
| Trélat parallelepiped [5] | Gaseous detonation | Length 0.40 m<br>Width 0.18 m<br>Height 0.14 m |
| INERIS L-wall [6] | Gaseous deflagration | Length 6 m<br>Thickness 0.15 m<br>Height 2 m |
| Vyazmina wall [7] | Numerical simulation (gaseous detonation) | Length infinite<br>Thickness 0.15 m<br>Height 2.50 m |
| Pellegrinelli wall [8] | Gaseous deflagration | Length infinite<br>Thickness 0.06 m<br>Height 0.10 m |
| Allain merlon [9] | TNT detonation | Height 1.50 m<br>Triangular section<br>45° sloping |
| Eveillard merlon [10] | Gaseous detonation | Height 0.20m<br>Triangular section<br>45° sloping |
| INERIS DRA08 table wall [11] | Gaseous deflagration | Height 0.30–0.50–0.70 m<br>Thickness 0.015 m |
| INERIS DRA08 medium scale wall [12] | Gaseous deflagration | Height 1.80–2.40–3.60 m<br>Thickness 0.60 m |
| INERIS GONCH spherical wall [13] | Gaseous detonation | Height 1.80 m<br>Thickness 0.60 m |
| INERIS GONCH planar wall [13] | Gaseous detonation | Height 1.80 m<br>Thickness 0.60 m |

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