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# EXPLOSION AND MITIGATION STRUCTURES

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***Abstract:***

***Man-made disasters like large explosion or a terrorist attack inflict widespread damage and represent major disaster. To minimize such type of effects apart from the precise knowledge of the mechanism of explosion and knowledge of the blast wave properties, the effective risk management through mitigation structures is vital.***

***Losses can be prevented and alleviate the impact by managing conditions of hazards, exposure and vulnerability. Disaster risk management involves three aspects 1) Prevention 2) Mitigation 3) Transfer and 4) Preparedness***

***This paper discusses primarily about the role of mitigation structures in disaster management and effective utilisation visco-elastic material in the development of mitigation structure in risk management. A encased soil with polymer film is considered as mitigation structure and its effective blast resisting capacity is discussed in this paper.***

***Key words:***

***mitigation structure, disaster, explosion, visco-elastic material, explosion***

## 1. Introduction

The effective energy yields of explosion which occurred at Hiroshima and Nagasaki in 1945 were determined by Lord Penny [1]. He determined it by observing the damage that occurred to various simple structures such as bent poles, toppled grave stones, and crushed paint cans, broken glass windows, dished in cabinet walls in the nearby vicinity of the explosion.

This research was further extended by various research workers by developing various types of passive gauges. These simple gauges were used to reflect some properties of the blast wave through its various modes of failure. Ewing et al[2] and Baker et al[3] have developed cantilever gauges with rectangular cross section to assess the effects of shockwaves. Later Dewey[4] studied the effect of TNT and ammonium nitrate explosions on the deformations of solder cantilevers.

The important feature of any large explosion in air is the blast wave it generates by forcibly pushing the surrounding atmosphere. This mainly results due to sudden energy release. The formation of blast wave is well illustrated by a graphical representation of a pressure pulse of an arbitrarily chosen initial configuration. The blast wave due to explosion creates very high impulsive pressure in initial few milliseconds and subsides rapidly with time. Thus to minimise the disastrous effect of explosion and to protect the humans and valuables the structure needs to be designed that will withstand the impulsive pressure.

## 2. Effects of explosion

Accidental explosion or man-made blast attack can cause devastating damage to infrastructure and buildings and results in widespread casualties. This happens, either directly as a result of the blast or indirectly when building elements fail catastrophically. In the current world of instability type of attack methods are the first choice of Terrorists and is likely to continue to do so as bomb making advice and expertise is increasingly available online for use by organised groups and lone operators alike.

To provide appropriate protection to various infrastructure and other facilities and to ensure the safety of building occupants and the protection of people in the public realm requires an integrated multidisciplinary approach to reduce the impact of such attacks.

 

### *2.1 Manmade explosions*

During terrorist attack the attacker aims to attain maximum destruction. For that it is targeted to achieve the release of impulsive and sudden pressure, through a rapid chemical reaction. This chemical reaction results into a sudden release of gas at very high temperature and pressure. For highly disastrous effect this chemical reaction has to take place in few milliseconds. The release of gas at very high temperature and pressure creates a shockwave known as blast wave. The result of explosion during terrorist attack is severe damage of the property as well as loss of human life. The damaging effect of explosion depends on the quantity of charge, its location and the type of material used.

The bomb which is designed and developed for other purpose than the military action is classified as improvised explosive devices (IED). In course of time IED's are used by terrorist groups in different forms such as 'Pressure cooker bombs', 'Suitcase bombs', depending upon the containers used. The another type is 'Vehicle borne explosions' known as VBIED's, in that different vehicles ranging from motor cycles to large good vehicles are used. In Mumbai 2008 blast at few locations like Parle (Mumbai) motor cars were used as VBIED[5]. Due to encasing of charge in vehicles as VBIED, and closeness of buildings in Parle area of Mumbai, the destructive effect was explosion was increased (Fig. 01). According to Wikipedia[6] in 2006 Malegaon(Maharashtra) blast cycles were used, while in 2008[7] Malegaon(Maharashtra) blast motorcycles were used. During 1993 blasts in Mumbai the explosives were placed in trains, resulted in high damages (Fig. 02).

Fig. 01: Remains of building after 2008 Mumbai blast (Source: bbc.com)

Fig. 02: Remains of train after 1993 bomb attack (Source:bbc.com)

### *2.2 Effects of explosions*

Normally due to any explosive attack high magnitude of damage to property and human life takes place. The various effects of any explosion can be listed as below;

- **Blast wave:** During explosion due to sudden rise in pressure and temperature expansion of gas takes place which results in moving pressure wave. That is called as blast wave. Fig. 03 shows pressure-time curve, which represents behavior of shock wave. The pressure rises from 0 to 62 kpa during just 5 milliseconds (from 37 to 42 milliseconds) and reduces to zero by 75 milliseconds.

- **Fire ball:** Whenever the large quantity of explosion takes place, a visible ball of fire is created which can be seen from a distant place also. For smaller quantity of explosion the fire ball is not that well defined and visible. A uncased or bare charge of 5 Tonne (Fig. 04) was used during Woomera trials where the fire ball was clearly visible (Fig. 05)

- **Crater & Brisance:** During explosion due to rise in temperature and chemical reaction a blast-wave is created. Due to debris throw a ditch created on ground which is called as Crater and the shattering effect created locally is called as Brisance. Fig. 06 shows the crater on ground due to high explosion during test.

- **Fragmentation:** these are shattered pieces of container, casings or objects that get engulfed within the blast wave and get thrown over long distances with a very high velocity. Fig. 07 shows the fragmentation of metal casing of charge.

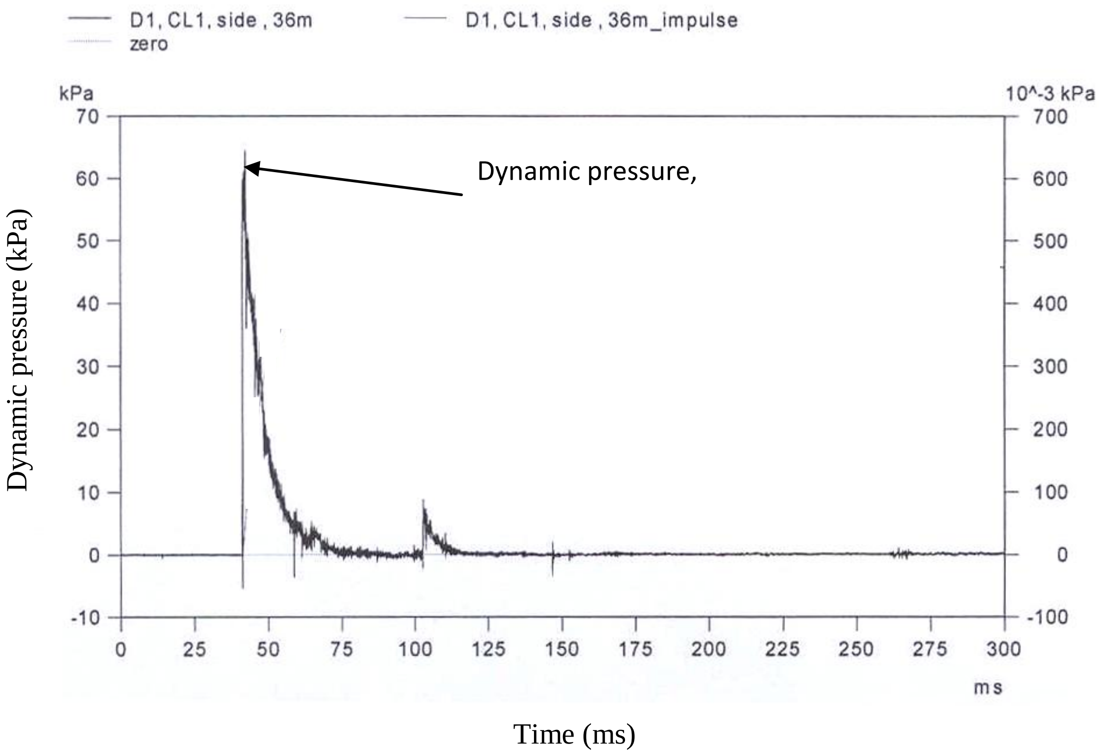


Fig. 03: Pressure-time curve of 5 tonne blast

Fig. 04: Uncased explosive charges used by author during trials at Woomera (Australia)

Fig. 05: Fire ball of 5 T charge during trials at Woomera (Australia)

### 3. Concept of tuning for effective blast mitigation

From above analysis and discussion the effects and severity of explosion is highlighted. To minimise the damaging effect of manmade explosions the right material must be chosen for mitigation structure. The vulnerability of assets and damages can be reduced by choosing the right material. From the Fig. 03, it is very clear that within first few milliseconds the pressure rises drastically and also reduces with similar fashion. If a chosen material for mitigation structure can tune itself with the blast wave and absorb that impulsive pressure, then the damaging effect of explosion will be minimised. Optimally dissipative visco-elastic material is the material that matches its damping frequency with the excitation frequency of shock wave front. Only drawback of using visco-elastic material for dissipation of energy of blast wave is that the shock wave front is transmitted in the form of a single pulse and converted into a stress wave. From this it primarily appears that visco-elastic material will not be suitable for dissipation of shock wave. But it is observed that if multi layered visco-elastic material is used it is possible to tune this material with the frequencies of the energy to be dissipated [9], [10].

The external layer subjected to shock wave should be linear elastic and isotropic. Newt layer to it should also be elastic but having modulus of elasticity lesser than the first layer. Acoustic mismatch will happen due to the variation in modulus and automatic stress tuning will happen. In visco-elastic material the energy dissipation increases with number of loading and unloading cycles, as well as with amplitude. Without excessive reduction in amplitude of stresses attain the large mismatch of impedance between the first and the second layer to achieve better tuning. Similarly for the dissipation of energy within the third layer ensure considerable amplitude of stress waves as compare to second layer. It is to be ensured that the frequency of stress cycles within visco-elastic material layer is as many as possible. The higher the frequency lesser will be the material needed. Frequencies associated with the range for tuning in which the properties needs to be studied. Currently very limited data based on study about visco-elastic material like polymers is available [11], [12], [13], [14].

## 4. Mitigation structures

Different types of mitigation structures are conventionally used since ancient types. Fig. 08 shows a typical bunker used as mitigation structure on border by the civilians to have protection from shelling. In recent time lot of research is going on to develop the effective and economical mitigation structure. An experimental work is carried out during field explosion test at Woomera (Australia) to check feasibility of using soil filled polymer film containers as a mitigation structure. Polymer is a visco-elastic material which can be used by matching its damping frequency with the damping frequency of the shock wave front created due to explosion. As the soil is encased within the film, it will dissipate the energy and minimise the chances of damage to the property and human life. As the visco-elastic material dissipates the energy like single pulse, encased soil is the best material to absorb the shock wave as it is fragile and granular material.

Fig. 08: Conventional Mitigation Structure -Bunkers in border areas for protection (source- India TV news)

Fig. 09: Mitigation Structures (Source: Field Explosion Test by Kulkarni at Woomera- Australia)

## 5. Conclusion

The study conducted by the author and supported with various observations during the field explosion test in Woomera, it is concluded that;

- Man made explosion results in damaging effect on human life and properties
- For effective blast mitigation a material should be chosen which can tune with the blast shock wave front.
- Polymer can be the best choice as visco-elastic material for mitigation structure
- Soil encased in polymer film is the best effective and economical mitigation structure
- Further research is necessary as less data is available on polymers as mitigation material

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