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An Investigation into the Use of a Vehicle for Improvised Blast Mitigation

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The Problem

Improvised explosive devices (IED) and/or vehicle borne IEDs (VBIED) are a worldwide threat and will remain so for the foreseeable future. Once located, the immediate response of the local security personnel would be to evacuate the area whilst specialists are called in to deal with the device. However, there may be circumstances that mean that bystanders cannot be moved, such as through prior injury, and therefore there is a need to investigate methods of rapid improvised blast mitigation. One such option is a vehicle as it could be moved quickly into position. But as there are a wide variety of vehicle shapes and sizes, as well as the need to optimise the positioning for maximum mitigation effectiveness, Hertfordshire Constabulary approached Cranfield University to assist in studying the feasibility of this tactic. The project was allocated to a syndicate undertaking the Addressing EOE Capability Caps (AECG) Module of the Explosive Ordnance Engineering (EOE) MSc. The four-person syndicate consisted of both civilian and serving military personnel, two of whom were on the first phase of their Ammunition Technical Officers Course.

Project Aim and Scenario

The aim of this project was therefore to investigate the consequence of using a vehicle as an improvised mitigation against blast and so potentially protect bystanders from an explosion. Secondly, to provide data on vehicle type and positioning in order to inform police policy. Due to the complexity of the task, the project goals had to be constrained and a simplified scenario investigated. In particular, fragmentation from both the VBIED and secondary fragmentation was ignored. The simplified scenario was thus as follows:

- **Location** – free field, i.e., no surrounding structures creating blast wave reflections
- **Threat** –141.6kg TATP (equivalent to a filled 120L drum)
- **Charge-bystander distance** – 15m separation between the seat of the explosion and the nearest bystander
- **Vehicle -** refuse collection truck. The choice of vehicle was left deliberately open by the Police, who made it clear that they would like to be able to consider the use of any nearby vehicles. Of particular interest were large publicly owned vehicles, such as refuse collection trucks, busses, or fire appliances. Given the high operational value of fire appliances and the potential for large amounts of fragmentation, a refuse collection truck was chosen for this study.

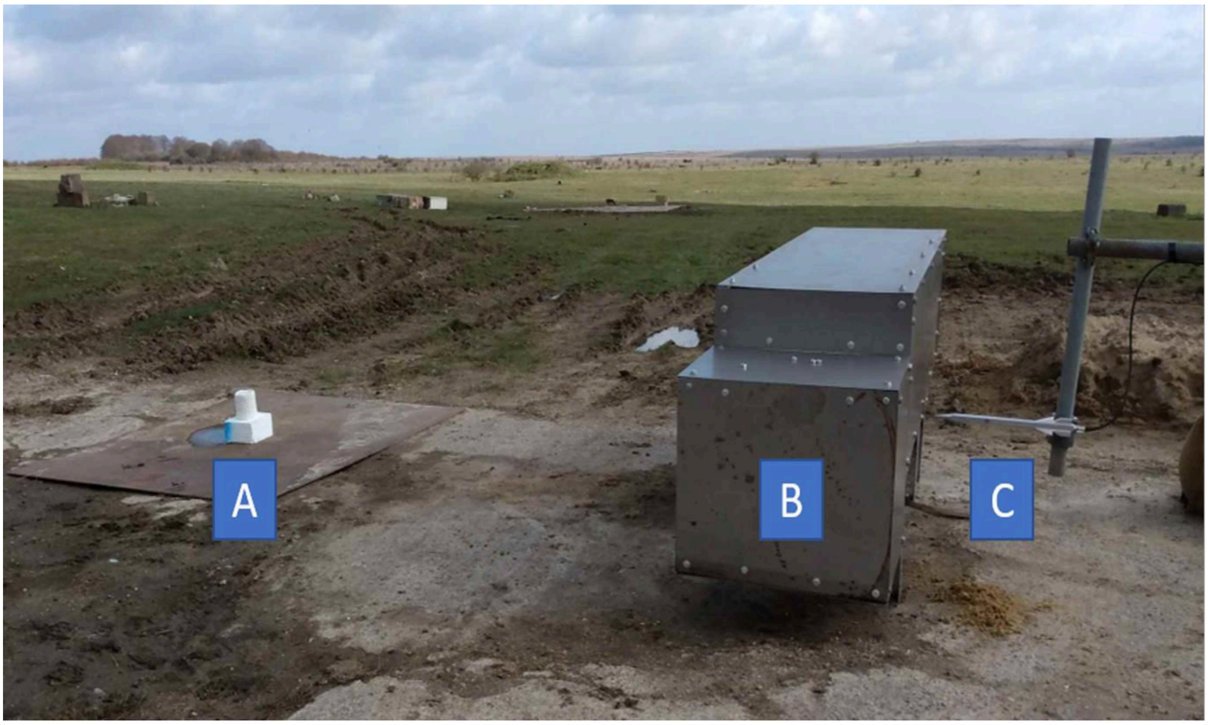
Experimental Approach

A combined experimental and computational approach was chosen to investigate the problem and provide the means to test the feasibility of the idea. A solely experimental project would be both impractical and inordinately expensive, whilst a computational approach requires validation. Similarly, the validation would require the design of a scaled down practical series of experiments. Hence the project compromised two main phases

- Design and testing of a scaled experiment to validate and optimise the chosen blast computational modelling software ProSair [1]
- Scaling up the computational model to full size to determine the blast pressure on a bystander

Phase 1 – Validation of computer modelling approach

The experimental set of serials was conducted at Cranfield Ordnance Test and Evaluation Centre (COTEC). The serials were run with a reduction from real life to scaled experiment of 5:1. This was chosen as a good balance between a sufficiently sizeable and yet still manoeuvrable ‘vehicle’ and a manageable charge size. Hence a model vehicle was constructed from slotted angle steel, 3mm steel plate and filled with sandbags to replicate a 26 tonne refuse truck. CONWEP [2] was used to determine the amount of C4 (chosen as a convenience over using TATP on the range) that would replicate similarly scaled blast overpressure equivalent to that which TATP would produce; this was calculated to be 725g of C4. The experimental set up is shown in Figure 1 with a blast overpressure gauge positioned where the bystander would be located (3m from the charge in the scaled experiment).



i)

ii)

Figure 1 – i) Experimental setup, (A) charge supported on polystyrene to provide ground clearance representative of a VBIED, (B) moveable mitigating vehicle, (C) pencil probe to measure incident blast pressure 3m from the charge; ii) model vehicle with ‘legs’ replacing wheels

The practical experiments were conducted in 4 serials, with 2 repetitions of each serial. Blast overpressures and high-speed video were recorded for each serial. Serial 1 was a bare charge with no vehicle, which established baseline values for overpressure and duration. These readings were then compared with the computational model as an initial check on the chosen approach. Serials 2-4 introduced the vehicle at designated distances from the charge; those being 0.75m, 1.5m and 2.25m (Figure 2).

Figure 2 – Still from a high-speed video with the vehicle positioned 2.25m from the C4 charge

As stated, the software ProSair was used for the blast simulation, with models designed to replicate as far as possible the scaled physical experiments conducted on the range. This allowed a direct comparison to be drawn between the results obtained from the physical experiments and those of the simulation. ProSair has a limited software library of explosives, neither TATP nor C4 is included whereas TNT is, hence CONWEP was again used to determine the TNT mass required for blast equivalence, which was determined to be 993g of TNT. For serial 1, the bare charge, the experimental results recorded a mean peak overpressure of 127.93kPa, with the modelling showing 112.61kPa (both measured at 3m from the explosion). The similarity between the two, a difference of around 12%, was deemed sufficiently accurate to continue. Hence the vehicle was introduced into both the explosive serials and simulations, with the measured peak overpressures given in Table 1. It can be seen that the difference between experimental and simulation peak overpressures reduced, furthermore and more importantly, both datasets indicated that the vehicle did have a mitigating effect on the blast.

Serial	Mean Peak Overpressure (kPa)	Simulated Peak Overpressure (kPa)
1 - bare charge	127.93	112.61
2 - vehicle 0.75 m from charge	92.13	83.9
3 - vehicle 1.5 m from charge	77.63	77.99
4 - vehicle 2.25 m from charge	79.5	86.54

Table 1 – Peak overpressures, from experiment and sim

Phase 2 – Full scale simulations

Finally, the ProSair model was scaled up to match the full dimensions of the proposed scenario, assuming a bystander located 15m from the explosion, and a charge of 116.1kg of TNT. Once again the vehicle distance from the point of detonation was altered; 3.75m, 7.5m and 11.25m (Figure 3). Results showed that positioning the vehicle furthest from the point of detonation resulted in the greatest reduction in the blast overpressure, from 106.13kPa with no vehicle, to 46.59kPa, a reduction of 56.1%.

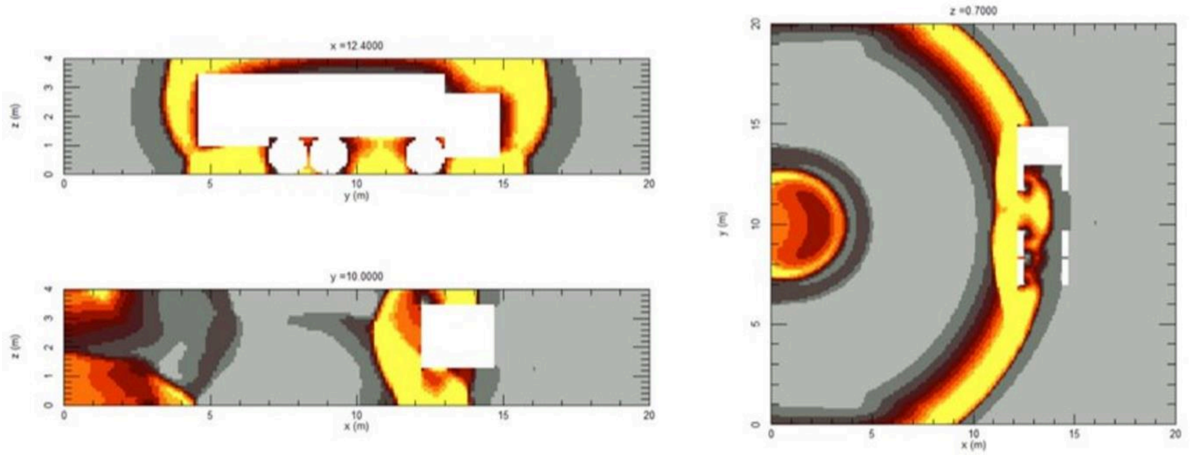


Figure 3 – ProSair simulation of a blast wave interacting with the vehicle located 11.25m from the blast site

Conclusions and Future Work

Whilst there are a number of known limitations with the computer modelling and especially with regards to (the lack of) fragmentation, this AECG project produced data which indicates that vehicles could be used as protection from blast. The probability / severity of injury to a bystander 15m from the blast can be assessed by comparing the calculated overpressures with fatality and injury curves [3-5]. Because overpressure falls off rapidly with distance, the chance of fatality was low even with no mitigation. However, several types of soft tissue injury would occur, but with the reduction from the vehicle, both the probability and severity of these injuries would be decreased.

Although promising, there is still much to do before the use of vehicles for IED mitigation can be accepted as a recognised and recommended tactic. Extensive future research will need to be undertaken to confirm the findings, both computationally and experimentally, and to incorporate the complexity and fragmentation of full scale vehicles.

Acknowledgements

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