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Editorial

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This themed issue of *Engineering and Computational Mechanics* focuses on design to resist the effects of blast from an engineering perspective, either from accidental explosion or through malicious attack. It looks at how the effects from these events can be understood and quantified for use in design and assessment of structures.

Recent industrial accidents, such as the vapour cloud explosion at the Buncefield oil depot near Hemel Hempstead, Hertfordshire, UK in 2005; the munitions dump explosion at Evangelos Florakis Naval Base near Zygi, Cyprus in 2011; and the fire culminating in an explosion at the West Fertilizer Company plant near Waco, Texas, USA in 2013, all illustrate the devastation blast can cause. Similarly, the bombing of the Alfred P. Murrah Federal Building, Oklahoma City, USA in 1995, and the commuter train bombings in Madrid, Spain in 2004 and London, UK in 2005 show how terrorists target people by destroying buildings and infrastructure. Mitigating risks to explosions and the effects of blast is often down to improving processes, whether this be industrial safety systems or security screening of public places, but the backstop is often the design of the structures themselves.

As a result of increased awareness of the risks and consequences, both in terms of loss of life and economic impact, blast resistant design is being specified more frequently for public buildings, important infrastructure and industrial facilities than in the past. This is only possible because of the advances being made in understanding blast, the techniques that have been developed to simulate blast and the design tools and standards that are emerging and available to planners, architects and engineers to help mitigate the effects of blast. No doubt inexpensive and powerful computing has contributed to the feasibility of numerical simulations. However, challenges remain and the papers and briefing articles presented in this issue of *Engineering and Computational Mechanics* present some of the latest research and developments to be made in blast resistant design.

An aspect of blast not often considered in the physics driven analysis and design processes that engineers and analysts use to develop their structural designs is the actual effects of blast on people. In the briefing note by Massouros *et al.* (2013) on the effects of blast on biological systems, experiences of injuries caused by buried improvised explosives to military personnel are described and analysed. Ways in which explosive energy interacts with biological systems is presented, along with how the data generated can be used to develop improved methods for studying blast injury processes.

Further research is summarised in the briefing note by Warren *et al.* (2013) which describes the UK Ministry of Defence Force Protection Research Programme. This combines two strands of engineering and underpinning research, as an example, work on the response of geomaterials to blast and projectile impact is described. Several research strands covering material testing at different scales are being used to develop material models for simulation eventually to be used in the development of geotechnical structures for blast protection.

The application of blast simulation to design by practitioners is emphasised in the briefing note by Reed (2013) on modelling for cost-effective resilience against blast. The point is made that numerical simulation of blast to reduce risk to as low as is reasonably practicable can also be justified to prevent excessive conservatism and cost in providing a suitable level of mitigation.

There is often a challenge in reaching a compromise in the specification of glazing between blast mitigation experts and architects with aspirations to create large open and light spaces. In the final briefing note by Morison (2013) the response of glazing and glazing systems to blast waves from an external explosion is explained. Backed up by evidence gained from analysis and testing, Morison details how, through choosing a suitable glazing system, the hazard level to building occupants can be reduced to acceptable levels.

In the first full paper Wilkinson *et al.* (2013) provide an assessment of the different basic modelling approaches used to understand bomb blast loading. Described as empirical, semi-empirical (phenomenological) and computational, the advantages and disadvantages of these approaches are assessed along with the different techniques most likely to be used in the design process. Following a description of the basic principles of blast wave propagation, each different modelling approach is described including the basic assumptions, and importantly their limitations. For the empirical approach TNT equivalency and scaled distance concepts are explained along with the types of blast scenario where empirical methods are applicable. Moving to semi-empirical techniques, the advantages of being able to introduce simple geometry and environments where blast is confined or partially confined is explained and how methods such as ray tracing have been developed. Finally, numerical simulation software based on computational fluid dynamics (CFD), also known as hydrocodes, is discussed including aspects such as meshing, the terms within the Navier–Stokes equations that are important to different types of blast event, and methods for dealing with fluid structure interaction where structural deformations are large. The authors strongly advocate an approach that is proportional to the level of certainty that exists in the underlying design basis; it is generally far better to consider a number of potential blast scenarios simply and establish design sensitivities, than to develop a sophisticated and exhaustive simulation of one event.

The next two papers are research based. Rigby *et al.* (2013) describes an experimental and theoretical programme which aims to provide simple corrections to the results obtained from empirical methods so that allowance is made for clearing effects. Clearing is the term used to describe relieving pressure as the blast wave passes the edge of a structure. It is shown that ignoring clearing and basing blast load on effectively infinite lateral extent, one of the empirical method-simplifying assumptions, may lead to highly conservative designs. Work involving comparisons of blast tests on flexible rectangular plates, using an arrangement that provides clearing and no clearing, and predictions of structural behaviour using explicit dynamic finite element (FE) analysis is described. Prediction of plate deflections corresponded well with experimental data, and it is concluded that the method developed by Hudson (1955) in an overlooked study can be reliably used to adjust the results of simple empirical methods to allow for clearing. This work should help extend the scope of empirical methods to structures with simple geometry and be especially useful in their concept design.

In the second research paper Pope (2013) is concerned with the design of a UK government full-scale experimental blast tunnel. Built in response to recent terrorist events, the primary role of the facility is to better understand the effects of blast within underground railway carriages. Numerical simulation of blast for both an empty tunnel and with a crowded train using a CFD code, and of the tunnel structure using explicit dynamic FE code, is described. The objectives of the simulation were to ensure the design was not excessively conservative, the facility would be safe to operate and the length and construction of the tunnel test facility would be representative of actual underground railway structures. Results of experimental proof tests are also briefly described. This facility is likely to be important in the development of future underground railway operations.

The final paper by Mullett *et al.* (2013) describes how detailed numerical simulation of blast loading from a vehicle-borne improvised explosive device has been used to help design a reinforced concrete building. With simulation undertaken using commercially available CFD and FE codes, the process of developing the analysis and structural design including sensitivities associated with blast location is detailed. Aspects covered include verification of blast loading, the treatment and importance of frangible walls, and the necessary additional checks associated with shear and torsion behaviour to ensure performance assumptions are met, along with a discussion of how the work was completed within a code of practice framework. The authors show how, with modest computing and care over the selection of modelling resolution, numerical simulation of blast can be carried out within a commercial environment with all the normal cost and programme constraints associated with modern building design.

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