Design Against Blast

Load Definition & Structural Response
Design Against Blast

Load Definition & Structural Response

Edited by

S. Syngellakis

Wessex Institute of Technology, UK
Preface

Terrorist attacks and other destructive incidents caused by explosives have, in recent years, prompted considerable research and development into the protection of structures against blast loads. For this objective to be achieved, experiments have been performed and theoretical studies carried out to improve our assessments of the intensity as well as the space-time distribution of the resulting blast pressure on the one hand and the consequences of an explosion to the exposed environment on the other.

This book aims to enhance awareness on and understanding of these topical issues through a collection of relevant, Transactions of the Wessex Institute of Technology articles written by experts in the field. The book starts with an overview of key physics-based algorithms for blast and fragment environment characterisation, structural response analyses and structural assessments with reference to a terrorist attack in an urban environment and the management of its inherent uncertainties.

A subsequent group of articles is concerned with the accurate definition of blast pressure, which is essential prerequisite to the reliable assessment of the consequences of an explosion. A variety of computer codes, associated with different types of explosive charges and ranges, exist for this purpose. These models range from simple empirically based to multi-physics, high strain rate finite element implementations of the conservation equations of continuum mechanics. Articles in the book address the experimental validation of available software as well as the comparison of their blast profile predictions.

Blast pressure profiles and histories are affected by the geometric configuration of the exposed structure and this particular issue is dealt with in the case of a round column. In the context of continuum modelling, the equation of state for the detonation products describes the work output from the explosive that causes the subsequent air blast. The reliable parameter calibration for this equation is an important topic also covered in the book.
Other papers are concerned with alternative methods for the determination of blast pressure. These are based on experimental measurements or neural networks. The latter model was trained and validated using as input blast threat scenarios and exposed geometry parameters and as output CFD predictions of peak pressures and impulses.

Numerical, theoretical and experimental studies on the effect of blast on components, structures and its occupants combine physics of detonation chemistry, shock physics, solid mechanics, structural dynamics, nonlinear material behaviour, human physiology and injury mechanics. A number of studies address general issues such as the generation of laboratory simulation of blast that reproduces failure modes of reinforced concrete elements observed in field tests, the link between non-ideal explosive and target configuration and the coupling of the response to the blast loading. The latter can be strong, particularly for close-in blast loading configurations; its effect is investigated in the case of flexible systems such as membranes, blast curtains, cable facades as well as compressible, soil-filled, concertainer walls. A final group of articles reports investigations on predicting the response of specific structural entities and their contents. Simplified methods for buildings, either taken from existing literature or based on experimental and numerical results are compared; another simplified method based on a beam-column damage element is tested on portal frames, which include laminated composite beams. Bridges have been given considerable attention as potential transportation targets; one paper describes a methodology for generating detailed design guidelines and another, an approximate method for the response of long span highway girders. Two articles on the protection of vehicles against explosive devices, such as mines and improvised explosive devices, put particular emphasis on occupant safety. The book concludes with studies on the effectiveness of steel-reinforced polymer in improving the performance of reinforced concrete columns and the failure mechanisms of seamless steel pipes used in nuclear industry.

Stavros Syngellakis (ed.)
The New Forest, 2013
Acronyms

ALE  Arbitrary Lagrangian- Eulerian
AMR  Adaptive Mesh Refinement
ANFO Ammonium Nitrate/Fuel Oil
ANN  Artificial Neural Network
AWE  Atomic Weapons Establishment
BG   Blast Generator
CAD  Computer Aided Design
CCD  Charge-coupled Device
CFD  Computational Fluid Dynamics
CFRP Carbon Fibre Reinforced Polymer
CJ   Chapman Jouguet
CMU  Concrete Masonry Unit
DLF  Dynamic Load Factor
DOT  Department of Transportation
DRDC Defence R&D Canada
DTRA Defense Threat Reduction Agency
EFP  Explosively Formed Penetrator
EMRTC Energetic Materials Research and Testing Center
EOS  Equations of State
FSI  Fluid Structure Interaction
GIS  Geographical Information System
GMDH Group Method of Data Handling
GRNN General Regression Neural Network
GSA  General Services Administration
GUI  Graphical User Interface
HE   High Explosive
HIC  Head Injury Criterion
ICP  Integrated Circuit Piezoelectric sensor
IED  Improvised Explosive Device
IMEA Integrated Modular Effectiveness Analysis
IRSN Institut de Radioprotection et de Sûreté Nucléaire (Radio protection and Nuclear Safety Institute)
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JWL</td>
<td>Jones-Wilkins-Lee</td>
</tr>
<tr>
<td>LSTC</td>
<td>Livermore Software Technology Corporation</td>
</tr>
<tr>
<td>LVDT</td>
<td>Linear Variable Differential Transformer</td>
</tr>
<tr>
<td>MEVA</td>
<td>Modular Effectiveness/Vulnerability Assessment</td>
</tr>
<tr>
<td>MLP</td>
<td>Multi-Layer Perceptron</td>
</tr>
<tr>
<td>NCAP</td>
<td>New Car Assessment Programme</td>
</tr>
<tr>
<td>NCHRP</td>
<td>National Cooperative Highway Research Program</td>
</tr>
<tr>
<td>PETN</td>
<td>Pentaerythritol tetranitrate</td>
</tr>
<tr>
<td>P-I</td>
<td>Pressure-impulse</td>
</tr>
<tr>
<td>PILR</td>
<td>Propagation, Interaction, Load and Response</td>
</tr>
<tr>
<td>RC</td>
<td>Reinforced Concrete</td>
</tr>
<tr>
<td>RHA</td>
<td>Rolled Homogenous Armour</td>
</tr>
<tr>
<td>SBD</td>
<td>Simulation-Based Design</td>
</tr>
<tr>
<td>SPH</td>
<td>Smooth Particle Hydrodynamics</td>
</tr>
<tr>
<td>SRP</td>
<td>Steel Reinforced Polymer</td>
</tr>
<tr>
<td>TNT</td>
<td>Trinitrotoluene</td>
</tr>
<tr>
<td>TROSS</td>
<td>Test Rig for Occupant Safety Systems</td>
</tr>
<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
</tr>
<tr>
<td>ZND</td>
<td>Zel’dovich-von Neumann-Doring</td>
</tr>
</tbody>
</table>
Contents

Integrated anti-terrorism physics-based modelling: threats, loads and structural response
F. A. Maestas, J. L. Smith & L. A. Young ............................................................ 1

A study of the JWL equation of state parameters of dynamite for use in airblast models
B. J. Zapata & D. C. Weggel ............................................................................. 11

A comparison of hydrodynamic and analytic predicted blast pressure profiles
G. M. Stunzenas & E. L. Baker ........................................................................... 23

Numerical determination of reflected blast pressure distribution on round columns
Y. Qasrawi, P. J. Heffernan & A. Fam .............................................................. 31

Theory and calibration of JWL and JWLB thermodynamic equations of state
E. L. Baker, D. Murphy, L. I. Stiel & E. Wrobel .............................................. 41

Prediction of airblast loads in complex environments using artificial neural networks
A. M. Remennikov & P. A. Mendis ................................................................. 53

Laboratory scale tests for internal blast loading
S. Kevorkian, N. Duriez & O. Loiseau............................................................. 63

Laboratory simulation of blast loading on building and bridge structures
M. M. Gram, A. J. Clark, G. A. Hegemier & F. Seible ..................................... 75

Non-ideal explosive performance in a building structure
Aerodynamic damping and fluid-structure interaction of blast loaded flexible structures
M. Teich & N. Gebbeken .......................................................... 97

Effect of silty-sand compressibility on transferred velocity from impulsive blast loading

Simplified evaluation of a building impacted by a terrorist explosion
D. Makovička & D. Makovička Jr .................................................. 121

Simplified blast simulation procedure for hazard mitigation planning
T. Tadepalli & C. L. Mullen .......................................................... 133

Blast-resistant highway bridges: design and detailing guidelines
G. Williams, C. Holland, E. B. Williamson, O. Bayrak, K. A. Marchand & J. Ray .......................................................... 143

Approximation of blast loading and single degree-of-freedom modelling parameters for long span girders
J. C. Gannon, K. A. Marchand & E. B. Williamson .......................... 153

Simulation-based design of vehicles exposed to blast threats for improved occupant survivability
R. T. Bocchieri, S. W. Kirkpatrick & B. Peterson .............................. 163

Blast protection in military land vehicle programmes:
approach, methodology and testing
M. Müller, U. Dierkes & J. Hampel ................................................ 177

Blast testing of CFRP and SRP strengthened RC columns
J. O. Berger, P. J. Heffernan & R. G. Wight .................................. 189

Analysis of the explosive loading of open-ended steel pipes
N. Rushton, G. Schleyer & R. Cheesman ....................................... 199

Author index .............................................................................. 209