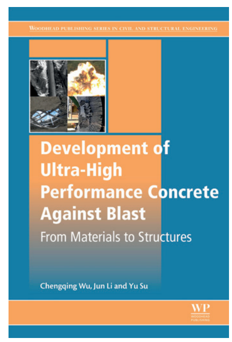
Review

This book will provide a valuable reference to those charged with protective design against severe blast loading, concludes Andrew Morrison.

Development of ultra-high performance concrete against blasts: from materials to structures

Authors: Chengqing Wu, Jun Li and Yu Su
Publisher: Woodhead Publishing
Price: £170 (paperback); £204 (e-book)
ISBN: 978-0-08102-495-9



Ultra-high performance concrete (UHPC) is a generic term for a developing material which combines ultra-high strength concrete (UHSC) with steel fibres in a wide array of compositions to provide tough, resilient construction materials. As such, UHPC is of potential interest to those charged with protective design. However, there is limited awareness of the physical properties of UHPC in the design community, coupled with a paucity of design guidance. This book provides detailed information on the composition, properties and performance of UHPC under blast loads.

This is achieved through a detailed and systematic review of recent research into this material, covering static, dynamic and blast testing, backed up by detailed numerical modelling. Initially, the book presents detail on the UHPC material, covering both the various nanoparticles used to provide a very dense matrix and the various steel fibres which provide the critical crack-bridging effect. The results of research and testing on concrete slabs are then presented, comparing the blast performance of normal-strength concrete (NSC) and UHPC slabs under stand-off and contact charges and incorporating various additional steel reinforcement. Guidance on the development of pressure–impulse (P-I) curves for slabs is provided and this forms a useful design tool.

The book then focuses on the performance of column sections, identifying such members as being critical to building performance, including damage control and prevention of progressive collapse. This interesting research addresses the direct effects of the blast but also the post-blast load-carrying ability of the damaged columns. Finally, the book presents research into a specific type of structural column, which utilises circular and square tubular steel sections filled with UHPC. Once again, guidance on P-I functions is provided.

The book highlights specific aspects which help to consolidate the potential applications of these materials. Initially, it is demonstrated that the addition of nanoparticles increases the compressive strength of high-strength concrete by about 10%; a further 30–50% enhancement of strength is achieved when steel fibres are included at dose rates of 1.0–2.5%. However, under flexural response, there was little benefit from low dose rates of 1.0%. There was a dramatic improvement in flexural strength (up to 300%) when the dose rate increased to 2.0–2.5%, with very high-strength microfibres. The fibre-to-aspect ratio (length/diameter) was shown to be important.

The book presents several numerical modelling exercises to replicate test results. Such topics are always of interest to designers, for whom numerical models are often the most effective means of design, where recourse to physical testing is not possible.

As well as structural performance, designers are very interested in spalling and the generation of fragments. In the slab testing programme, the UHPC samples did not generate fragments, compared to the NSC slab which was heavily damaged and generated large amounts of fragments. This important benefit is attributed to the crack-bridging effect of the steel fibres, coupled with controlled overall slab response.

Further guidance on the use of numerical modelling to predict damage levels was provided in relation to element erosion. Erosion is a modelling approach where elements which have yielded are deleted from the model. However, it is well known that this can compromise accuracy due to the loss of mass from the numerical solution. While concrete fracture strain occurs at 1–2% strain (taking account of strain rate enhancements), the researchers advise using a high tensile strain value of 10% before permitting element deletion.

The emphasis placed by the latter half of the book on columns is useful. Columns play a critical part in building safety, as evidenced by progressive collapse requirements. The book provides useful guidance on the amount of damage experienced by UHPC columns and the resulting residual load-carrying capacity.

This is a specialised book, describing the performance of slabs and columns under severe blast loading. For those charged with such designs, it is a valuable reference, providing a detailed overview of material properties and how the selection of materials affects the blast resistance. While the loading is severe and the structural responses highly non-linear, the book is easy to read and there are numerous colour graphs and photographs to aid understanding. The comparison to numerical modelling is particularly useful since it is not always feasible to conduct testing of proposed designs.

Andrew Morrison
CEng, MIStructE, MICE

Andrew Morrison is a chartered civil and structural engineer who has specialised in structural dynamics including blast-resistant design. His experience has highlighted the vulnerability of reinforced concrete, particularly to close-in blasts, and the secondary threats posed by the generation of fragments.