Editorial

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Structural engineering is a mature discipline and perhaps uniquely in the UK context, one that has its own governing institution separate from the overarching discipline of civil engineering. This is proof of the seriousness with which society views the safety of engineered construction, making structural engineering a relatively conservative discipline with strong adherence to codes and standards, particularly in the case of extreme loadings. Nevertheless, as experience and knowledge of response of materials and structures under foreseeable exceptional conditions (e.g. natural and man-made hazards such as high winds, earthquake, fire and blast) has grown, most notably in earthquake engineering, a greater willingness to allow greater leeway to the engineer is evident. This development is often loosely referred to as ‘performance-based structural engineering’ (PBSE) or simply ‘performance-based design’. Although these concepts remain nebulous at this stage, much of current structural engineering research is ultimately about developing greater knowledge and understanding to quantify causes and effects (loads and responses), ideally within a framework accounting for uncertainties in both, in order to progress towards this structural engineering ‘holy grail’.

Research on understanding the response of structures to fire has seen significant growth in the past four decades. The beginning could arguably be traced to the pioneering work by the Swedish Institute for Steel Construction in the 1970s, when the first steps towards proper quantification of ‘cause and effect’ was attempted and tools were developed for engineers to use. Subsequent work in UK, led by the Building Research Establishment the then British Steel, followed a number of accidental fires (e.g. Broadgate in 1990 and Churchill Plaza in 1991) that starkly exposed the inadequacy of the assumptions that governed structural fire resistance calculations in steel-frame composite structures. Full-scale fire tests at Cardington (mid-1990s) confirmed that the behaviour of steel-frame buildings was much more robust than accounted for by the simple but naïve ‘single element’ and ‘standard fire’ assumptions, which associated ‘failure’ with a certain temperature. These assumptions had the effect of taking the structural engineer out of the design chain as all that was needed was ‘adequate protection’ from fire. However, the understanding gained from the Cardington tests and subsequent computational modelling work was instrumental in developing a strong movement towards PBSE in structures in fire. Some of the earliest examples manifested themselves in office buildings going up in UK in the 2000s as the straitjacket of building regulations has been progressively relaxed. However this decade began with

the terrorist atrocities of September 11, 2001, which saw three tall steel-frame structures (World Trade Center 1, 2 and 7, New York) collapse largely because of the effect of fire. This tempered the initial euphoria in the steel industry after Cardington. Early feeling in some quarters in the aftermath of September 11, 2001, that reinforced concrete (RC) frame structures are perhaps safer in fire, have also faced the ‘reality check’ of a number of accidental collapses (e.g. the Gretzenbach underground car park in 2004 and the TU Delft Architecture Faculty in 2008). These events have shown that there are no simple answers and underscored the importance of both researchers and practitioners having a proper understanding and have highlighted the need for more research.

Although a great deal of progress has been achieved, in its current state of development, ‘structures in fire’ research is still way behind say the comparator sub-discipline of earthquake engineering and a great deal of fundamental work remains to be done in order to close the gap. A great deal more full-scale and precisely controlled testing is needed to address a range of issues in both steel and RC construction and to understand how fire induced damage may progress from material to local and then global structural failures. In order to make PBSE feasible, the complex features of behaviour observed in tests and real fires must be reproduced in analytical and numerical models, which should then be made as simple as possible (without losing the key features and predictive capability). These simplified models can function as the necessary analytical tools in a PBSE framework that would enable engineers to provide probabilistic estimates of structural response to real or design fires and probabilistic estimates of initial and consequential costs of choosing different structural fire resistance design options.

The research community in this area has grown exponentially in the last decade and the numbers of papers submitted to the biennial conference (SiF) in the field have grown tenfold in roughly ten years. Some of the papers in this special issue are extended versions of ones submitted at the SiF’10 conference (at the University of Michigan, 2010) and others represent routine research and development work at the major research centres in this field, most of whom are represented among all the co-authors of articles herein. The first two papers, by Vassart *et al.* (2012) and Sharma *et al.* (2012) describe two full-scale fire tests and some preliminary modelling. The former reports on testing of a long-span floor system using steel cellular beam, an

increasingly popular choice as it provides large, modern, open-plan office spaces. The latter describes the world's first fire resistance testing of a full-scale RC frame, which had first been subjected to simulated seismic damage. In addition to offering deep insights into structural behaviour, the data from these tests is also an extremely valuable resource for validating computer models. The next paper by Kodur and Dwaikat (2012) offers a useful engineering perspective of the highly complex issue of spalling in concrete subjected to high thermal gradients (especially relevant to high-strength concrete). The fourth paper by Adelzadeh *et al.* (2012) presents a set of tests and numerical modelling to assess the fire resistance of fibre reinforced polymer (FRP)-strengthened concrete members contributing towards resolving the difficult issue of repair and retrofit using FRP materials, which is often questioned in this context. The next paper by Lou *et al.* (2012) provides useful insights into the change in properties of high-strength steel bolts after having been exposed to fire. The last two papers by Abu *et al.* (2012) and Cashell *et al.* (2012) present their recent work on the key issue of the ultimate load carrying capacity of composite floor slabs in fire. The former identifies limits to the applicability of the popular Bailey–BRE method and the latter presents a series of very useful tests describing the key failure mechanisms and also provides a simple expression for use in design. The issue concludes with a review of Tom Lennon's (2011) *Structural Fire Engineering*.

In addition to the diversity of topics it may also be apparent from reading the authorship of the papers that there has been a conscious attempt to solicit papers from all geographical regions of the world, particularly where these represent significant collaborations, either between academics across national frontiers or between industry and academia. It is therefore hoped that the papers in this special issue provide a global snapshot of the status of research in this field at this point in time and would therefore be of interest to the readership of this journal.

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