COMPUTATIONAL FIRE ENGINEERING – DO WE HAVE WHAT WE NEED?

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This presentation will attempt to address the issue of whether the engineering design community has the knowledge, data and tool sets required to undertake advanced evacuation analysis. In discussing this issue I want to draw on examples not only from the building industry but more widely from where ever people come into contact with an environment fashioned by man. Prescriptive design regulations the world over suggest that if we follow a particular set of essentially configurational regulations concerning travel distances, number of exits, exit widths, etc it should be possible to evacuate a structure within a pre-defined acceptable amount of time. In the U.K. for public buildings this turns out to be 2.5 minutes, internationally in the aviation industry this is 90 seconds, in the UK rail industry this is 90 seconds and the international standard adopted by the maritime industry is 60 minutes. The difficulties and short comings of this approach are well known and so I will not repeat them here, save to say that this approach is usually littered with “magic numbers” that do not stand up to scrutiny. As we are focusing on human behaviour issues, it is also worth noting that more generally, the approach fails to take into account how people actually behave, preferring to adopt an engineer’s view of what people should do in order to make their design work. Examples of the failure of this approach are legion and include the; Manchester Boeing 737 fire, Kings Cross underground station fire, Piper Alpha oil platform explosion, Ladbroke Grove Rail crash and fire, Mont Blanc tunnel fire, Scandinavian Star ferry fire and the Station Nightclub fire.

An alternative methodology that recognises and attempts to address these short comings is provided by the Performance Based Approach (PBA). While there are many variations of this theme, essentially it involves the concept of the Available Safe Egress Time or ASET and Required Safe Egress Time or RSET. For a particular application the ASET may be based on the time required for the smoke layer to descend to head height while the RSET may be the time required for the occupants to vacate the structure. Put simply, the ASET must be greater than the RSET. Clearly, the circumstances of the scenario under investigation will determine both the ASET and RSET and several relevant scenarios will need to be examined before any conclusions can be reached. As part of this process, risk analysis is performed in order to identify credible fire scenarios (including fire loads, fire evolution, fire size etc) along with credible evacuation scenarios (including number and type of people, occupant response characteristics, etc). Thus in a PBA, the ASET is not arbitrarily set as an invariant magic number but determined for the scenario. Equally, it is not assumed that the RSET will be met simply by following set configurational rules but must be determined for the scenario under consideration. Computer based evacuation, fire and structure models - of which there are many - together with reliable data are used to assist in the determination of both the ASET and the RSET. In this way computer based fire, suppression, structure and evacuation models provide a means by which the complex interacting system of structure/environment/population can be assessed under challenging design scenarios. Several years ago I coined the phrase Computational Fire Engineering or CFE to describe the use of computer models within the PBA. In the remainder of this paper we will concentrate on human behaviour and evacuation models however, the comments apply equally well to the other models used in CFE.

Numerous computational tools are available and routinely used in CFE. However, without exception, all models have limitations. Current levels of model sophistication and application reflect our current understanding of human behaviour in evacuation conditions. In one way or another, these limitations are due either to the failure to incorporate known behaviours within models, or to our collective lack of understanding and/or quantification of evacuation behaviours. It is the responsibility of the model developer to clearly identify these limitations and the responsibility of the fire engineer to understand the stated limitations and utilise the model accordingly. However, as architects design more innovative structures and regulators strive to maintain or improve safety and reliability standards, the fire engineer is expected to demonstrate performance in ever more complex and demanding evacuation scenarios. This increases the demands on model capabilities which in turn challenge our understanding of human behaviour in evacuation situations.

An example is provided by the maritime industry. IMO has adopted a methodology where the ASET is set by a prescriptive limit while the RSET can be determined by computer simulation [1]. To determine the RSET the submitted design is subjected to four benchmark scenarios each evaluated by computer simulation. The nature of the scenarios is prescribed and is acknowledged to be artificial in nature, with the vessel in an upright orientation and not subject to dynamic conditions of roll. These limitations were imposed on the simulations as there was insufficient data to determine how passengers would perform in adverse conditions. Furthermore, the abandonment phase was not included in the simulation as data was not available to adequately specify the abandonment phase. In response to these limitations, the EU under Framework 5 have funded the FIRE-EXIT consortium [2] to collect human performance data under conditions of adverse static orientation and dynamic motion and to collect abandonment data from laboratory trials. In addition, the IMO requirements currently specify arbitrary response time data for passengers. FIRE-EXIT will also attempt to collect response time data from live evacuations held at sea. This information is being used to assist in the development of advanced ship evacuation models and to provide data that can be used in CFE calculations.

There are numerous areas that warrant further research in the building industry. Following the World Trade Centre (WTC) disaster the design of high-rise buildings has been a focus of attention. Issues under scrutiny include; phased evacuation; occupant response times; occupant deference behaviour in merging flows on stairs; and the formation, maintenance and behaviour of groups. These issues are being investigated through several research projects addressing the WTC (see [2,3] and this proceedings) which will yield improved understanding of these issues which in turn will lead to improved models and datasets. Other issues that require urgent attention include the concept of safe refuges – how long will people be prepared to wait; the use of elevators for evacuation – what protocols should be adopted to achieve an efficient and orderly evacuation; and what is the likelihood that existing but seldom used emergency exit routes will be adopted?

Of more concern is the rail industry. Within the UK, an arbitrary evacuation performance has been specified for rail vehicles that does not appear to be based on modern fire engineering principles. For example, evacuation of rail vehicles to a platform must satisfy an ASET of 90 seconds [4]. While it is not clear how this prescriptive “magic number” was derived, it would appear to have been borrowed from the aviation industry where the equally indefensible “magic number” of 90 seconds is used to specify ASETs for aircraft ranging from small 40 seater commuter aircraft to the 550 seat super jumbo A380. The validity of other specified criteria such as exit flow rates for carriage end doors to track level of 30 passengers/minute and 40 passengers/minute for evacuation to adjacent vehicles is also questionable. Other official emergency exits described in emergency placards, such as window exits, do not appear to have their evacuation performance capabilities specified at all. Clearly this is an area that requires considerable attention if a rational approach to rail vehicle evacuation is to be adopted.

If CFE is to play a useful role in the design of safer structures, further targeted research is needed to generate the data required by complex CFE applications and to provide the knowledge required to improve the capabilities of our CFE tools. Without this research, the PBA will eventually become as inappropriate as prescriptive codes, littered with a new generation of magic numbers.

REFERENCES

1. IMO MSC Circular 1033, May 2002.
2. http://fseg.gre.ac.uk
3. Galea E.R. and Blake S.J, Collection and Analysis of Data relating to the evacuation of the Word Trade Centre Buildings on 11 September 2001, Report produced for the UK ODPM, to appear 2004.
4. ATOC document "Vehicle Interiors Design for Evacuation and Fire Safety", AV/ST9002, Dec 2002.