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Fire safety engineering at a crossroad

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ABSTRACT

Fire safety engineering (FSE) has become widely accepted throughout the world. This is quite an accomplishment for a young engineering discipline. Fire safety engineers are employed by public and private sector organizations of all types. We are involved in almost all major building and infrastructure projects, enabling amazing buildings to be designed, constructed and occupied. We play critical roles in high hazard industries, helping to mitigate risks and achieve acceptable levels of safety. We undertake groundbreaking research and develop new technologies aimed at reducing the impacts of unwanted fire. However, as an engineering discipline, we lack several attributes that one might expect to see in a mature discipline, including a robust analytical engineering framework. We have not experienced any transformational changes in technology or practice in some time. FSE degree programs and recognition of FSE as a unique discipline remain lacking in several countries, leading to wide variation in the level and consistency of fire safety performance delivered. This has unfortunately led some to question the competency and the efficacy of the profession, in some cases resulting in more regulatory control over the fire safety engineering analysis and design of buildings. The net result is that we are at a crossroad. We face some significant challenges, but we have the opportunity to shape an amazing future. If we are up to the challenges and take advantage of the opportunities, we have a chance to evolve the discipline towards maturity and greater respect. In this article I outline my view of the current situations, some of the challenges we face, steps we might take to overcome them, and areas for research, development and implementation into practice concepts that can lead to a promising future.

Current situation: an adolecent discipline

At the *6th International Symposium on Fire Safety Science*, I presented an invited lecture on international experience in the development of performance-based fire safety design methods [1]. At the time, I observed that fire safety engineering (FSE) had developed to the point where it had become an accepted, if not fully mature, engineering discipline. I based my assessment of the maturity of FSE on characteristics identified by the internationally respected earthquake engineering Professor C. Allin Cornell [2]. Today, as in 1999, I would argue that FSE is a healthy adolescent. Over the past three decades, research has become more focused on addressing the needs of FSE practice, the essential elements of a framework and vocabulary have been developed, and many practitioners appreciate where and how the current methodologies can address their problems [3]. For the most part this been facilitated by the publication of numerous FSE standards, guidelines and

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handbooks e.g., [4–12], which are widely used and/or being developed for use in practice. It has also been facilitated by the promulgation of performance-based building regulations in numerous countries [13,14]. Data, research reports, tools and methods are also widely available via the internet (e.g., see websites for such organizations as BRANZ, NIST, NRCC, SP, etc.). Nonetheless, while the current situation is encouraging, the ongoing development of FSE remains largely uncoordinated, with rapid advancement in some areas and incremental or no advancement in others, with significant gaps remaining. I touch on some of the gains and gaps below.

Computational tools

The past two decades has seen considerable advancement in computational tools for FSE. Advancements in cost-effective computing and graphical user interfaces has resulted in widespread use of computational fluid dynamics (CFD) for fire effects modeling, finite element (FE) tools for fire response of structures analysis, and human behavior and evacuation models. However, how well they work, and more importantly, how well we use them, remains a concern e.g., [15–19].

The FSE and PB code frameworks

Although a general framework and vocabulary for FSE exists, in nearly all of the standards and guidelines cited above, the basic approach is to provide general guidance regarding what should be considered in a FSE analysis, but detailed guidance on how to actually conduct FSE analyses is missing. In addition, guidance regarding how to integrate fire safety performance with all other required and desired performances for a building – in normal and emergency situations – is also missing. Details which are lacking include means to quantify performance expectations and measures, characterize targets and their vulnerabilities, quantify fire threats, and evaluate the building and fire safety systems' ability to deliver desired performance in normal and emergency conditions. In addition, guidance for how to address uncertainty and variability across all aspects of FSE analysis is largely missing. The net result is that fire safety engineers are free to select data, tools and methods of their choice, in consideration of scenarios which they think are important (with varying degrees of stakeholder involvement), evaluated against criteria they select, with the potential for no explicit consideration of uncertainty and variability throughout the life of the building. These gaps and lack of detailed guidance are significant contributors to the wide variation in safety performance being delivered in practice and the growing lack of confidence by regulators e.g., see [3,18,20]. Until we find better and more consistent ways to address some of these issues, we will not achieve the level of respect and confidence needed for our engineering peers and enforcement officials to universally accept FSE as a mature engineering discipline. Some insights have been provided in this area, looking at parallels to other engineering disciplines as well as taking fresh approaches e.g., [21–24], but more effort is needed. Advances in the performance building regulatory structure is needed as well, so as to get the right mix of stakeholders, working in the right arenas, to agree how safety performance is to be defined, quantified and implemented into regulatory, design and safety management practice.

Education, qualifications and ethics of fire safety engineers

We have a lack of adequately qualified fire safety engineers, particularly those with appropriate education, the confidence and wisdom of experience across a diversity of applications, and the ethics and accountability needed to help foster confidence in the profession. At the same time, we have a continued reliance on longstanding prescriptions and rules of thumb to guide decisions, even when the science and data exist to better support decisions, and proper application of the science is not mandated. The net result is that critical fire and life safety decisions are sometime being made – and allowed to be made – by people without proper credentials. In some cases there is a lack of FSE university degree programs. In others there is a lack of regulatory controls (defining and requiring minimum qualifications) and enforcement. However, in some cases it is ignorance and hubris, where a professional thinks he knows it all actively rejects helpful data and information. Sadly, we have even seen intentional falsification of analysis or misrepresentation of analytical or computational outcomes. Unfortunately, these issues are not new, but have been raised by a diversity of individuals and groups going back almost 20 years e.g., [1,2,13,15–20,25–31]. More FSE education is needed. More certification of qualifications is needed. Stronger ethics are needed. We should look to the medical profession here: first, do no harm.

Lack of data and reluctance to qualify data for FSE

While we have seen significant growth in the availability of computational analysis tools, the availability of data for use in these tools and in engineering analysis in general remains a problem across all FSE areas – from fire properties of materials to human factors. This is of particular concern with respect to the widespread use of models, since the appropriateness of the analysis is related to the appropriateness of the data. In part this is driven by the perception amongst some that advancements in computational tools have diminished the need for experimental data, when in fact it is just the opposite: experimental data are needed to support model development, verification and validation e.g., [32,33], as well for use in analysis and design applications e.g., [16]. Without experimental data, we lack a fundamental basis for application of our computational tools. The lack of usable data for engineering analysis is also impacted by reluctance within the industry to develop or accept more scientifically-based standard tests for fire properties of materials. While some fundamentally-based test methods exist, many others are 'pass–fail' tests which yield little or no data for use in performance assessment or computational modeling. This has been identified by the International FORUM of Fire Research Directors (FORUM) as a critical need in moving the profession forward [34]. This is not to say there are no sources of data: research laboratories such as the NRC (Canada), BRANZ (NZ), SP (Sweden), NIST (USA) and others publish heat release rate, human behavior data, and more e.g., [35,36]. However, it can be difficult to find data which includes information about the experimental set up, data collection and related parameters. And, with practicing engineers often defaulting to readily available data – whether it fits well or not – due to project time or cost restrictions, the outcomes can be problematic. Recognizing the challenges with data sharing exist, including confidentiality, proprietary and profit concerns, it would be encouraging (though not a foregone conclusion) to think the FSE community can come together and develop a global platform for sharing fire safety engineering data to help advance the discipline. Such a concept is being promoted by Alvarez with his Vulcan Initiative concept [24]. It remains to be seen where this goes. Past attempts sadly failed [35].

A focus on tools over good engineering and design

Application of an engineering tool, such as a computational fire effects model, does not constitute engineering. That is modeling. Engineering is about investigating a problem, properly defining the problem, and developing solutions for the problem using available knowledge and technology, taking appropriate consideration of the uncertainty around the problem and implementation of the solution. Not all problems require that complex tools be applied as part of developing a solution. There is a need to find a balance between when 'simplified' methods are appropriate and when 'comprehensive' analysis is needed, and what makes for 'good analysis' versus 'good design'. When we are a mature discipline, we should not be undertaking and charging for analysis which is not needed. We should not be doing that now. In the short term, it would help if we all work from a level playing field. This can be helped, in the short term, but better defining and bounding the FSE process. If loads, criteria and methods of analysis can be defined for a large subset of buildings, that can facilitate a level of consistency and regulatory certainty in the market. That is good for all. Such 'prescribed performance' can replace truly prescriptive codes without allowing too much flexibility for inadequately qualified or unethical engineers to misuse. There will still be plenty of need for detailed analysis – by qualified engineers – to facilitate innovative designs. In addition, the 'standardization' of 'simplified' FSE can increase confidence in the regulatory community and therefore facilitate more opportunities for innovative analyses and designs. It will also facilitate moving to the next level: risk-informed and performance-based analysis, employing complex computational tools, within an analytical engineering framework.

So what does the future hold?

You may not agree with my assessment of the current status of FSE. My knowledge of advances in fire safety engineering science is incomplete. My knowledge of practice around the world is incomplete. Also, like everyone else, I view the situation through personal filters. Nonetheless, it is a view of where we are at. Trying to look ahead is all the more challenging. I do not have a crystal ball through which to divine the future. I can only postulate possibilities based on where I think we are, and what might happen if we choose different paths. I elaborate on these in [3]. Here I offer just a few ideas to stimulate action. In the end, it is the multitude of practitioners and researchers out there who are far more knowledgeable than I, who are needed to step up to the challenge and move us forward.

- We need to better define what FSE is and the sub-specialties which are involved. We need to define and implement globally-consistent minimum educational requirements, occupational standards and competency qualifications to facilitate globally consistent recognition and acceptance. We need to certify those who are qualified and otherwise help to raise the competency bar overall.
- We need to facilitate and support fire science and engineering programs which can deliver practitioners and researchers with the capabilities and vision to realize transformational change.
- Competition within the academic community needs to be reduced and collaboration increased. We should follow the lead of Stanford University, the Massachusetts Institute of Technology and others and make course material freely available. We should go further and share faculty amongst universities, allowing all students to learn from the best worldwide.
- We should embrace the short-term approach of defining loads, criteria and methods of analysis for a large subset of buildings, and incorporating that into building regulatory systems, while pushing for development of more holistic, integrated, risk-informed and performance-based frameworks for FSE and building regulation.
- We need to stop being parochial and establish a truly open and international forum for advancing information sharing, research and development. We should not continue to tolerate each organization, country or economic region doing its own thing, but push for consolidated and collaborative efforts where a plan is agreed, the work is divided complementarily and not duplicated, and where the outcomes are universally implemented. Global cooperation is imperative. Globally available databases are essential. When we achieve this, the level of respect we receive will increase

dramatically, as will the level of confidence in the application of FSE will increase. While some competition is good, and it may still exist between private sector entities for profitability reasons, we need to find a mechanism that works for the public good as a top priority.
- To enable the above we need to step up our game in seeking and lobbying for research funding for FSE and related areas of research and practice. Globally we need to be funded at levels of at least US$100M per year for at least 10 years to make a credible start.
- In addition to the above issues, funding towards new technology is needed. We need to push the envelope with tools and technology across a wide range of areas: sensors, communication networks, risk and decision modeling and control systems, robotic and otherwise automated systems, suppression agents, safe, sustainable and resilient materials, and more.
- To chart a globally-agreed path to address longer term issues we need another internationally significant and intellectually provoking Airlie House, Warren Centre, or equivalent event. Not a one- or two-day workshop, but a week or two, in residence, brainstorming and planning event aimed at charting the future.

Summary

Fire safety engineering is a great profession. We help safeguard society from destructive fire. But, while we have made great strides as a discipline, and we are enabling amazing structures to be built, in my opinion we still face challenges, including many associated with gaps in data and knowledge, variability in the application of FSE and the designs which result, and inadequate levels of education and lack of experience in key areas of the profession. We have accomplished much, but we can do significantly more. I hope I have challenged you somewhat with my views on where we are as a profession, and where we can go, and that you young, motivated and talented engineers and scientists out there take up the challenge and lead us proudly into the future.

Acknowledgments

The basis for this article is a paper which I prepared for the Society of Fire Safety's *2011 Fire Safety Engineering Conference: Raising the Bar* [3], updated to reflect new insights, perspectives and activities since the 2011 conference. I thank the SFS for allowing me to republish some of my thoughts here.

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