

Issues and Opportunities for the Future of Fire Engineering

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presented by
David A. Lucht, P.E., FSFPE
Professor and Director Emeritus
Center for Firesafety Studies
Worcester Polytechnic Institute

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Like most areas of science, engineering and technology, fire engineering has undergone an amazing transformation in a single generation. Many of us can remember the days when:

- There were no postgraduate degree programs in fire engineering
- There were no university level textbooks
- There was no professional engineer registration/licensing system
- Computers were not used in design
- Computer fire modeling was unheard of
- The scientific foundation was virtually nonexistent
- Statistical fire databases were limited at best and mainly confined to the insurance industry
- Regulatory codes were strictly empirical and prescriptive
- The insurance industry mainly dominated the scene
- Consultancy practice was virtually non-existent

Today, of course, things are very different. It would be unusual to attend a contemporary fire conference and not hear speakers discussing the latest developments in computer modeling, performance-based codes and design methods. Thanks to the vision and leadership of people like David Rasbash, university-level research and education in fire engineering have been established. Important textbooks have been published by distinguished scholars like Dougal Drysdale. And, thanks to pioneering research done at university, industrial and government laboratories worldwide, the scientific literature has built a whole new foundation for engineering practice. Consultancy is now in the mainstream. Many would claim that fire engineering has finally come of age.

Future Issues and Challenges

Indeed our field has matured greatly. Fire engineers now have a more sophisticated set of tools with which to work. They are better equipped to help their clients manage risk more effectively and efficiently. But, of course, there are still opportunities and issues for the future. The following have been selected for special mention:

- Research needs – gaps in the body of knowledge
- Practice needs – better tools for dealing with uncertainty
- Social needs - public policy and cultural gaps

Research Needs

It seems research needs never end. As more questions are answered in the laboratory, more unknowns enter the picture.

The last formal assessment of research needs in the United States was performed in 2003 by the National Academy of Engineering/National Academy of Sciences, National Research Council [1]. Using a panel of distinguished experts, important research needs were identified in a host of areas ranging from fire fundamentals to fire protection system performance, engineering tools, human behavior and public policy.

Some of the most significant findings had to do with performance-based practices. The panel noted that:

- Performance-based codes offer real promise for regulators and public officials to help them better understand risk and building safety performance in communities
- In order for performance-based codes to succeed, engineers must be able to predict how buildings will perform under fire conditions
- There are significant gaps in the data and knowledge base needed to support performance-based codes, engineering tools, predictive models and risk assessment

The panel also examined the role of universities and fire research funding, noting:

- University level fire research has all but evaporated in the United States over the past three decades
- During this period fire research grants to universities from the National Institute of Standards and Technology (the US government fire laboratory) declined 85% when adjusted for inflation
- In addition to choking off new scientific discovery, this decline has all but eliminated the production of young scholars with career commitment to inquiry and teaching in fire safety sciences

Practice Needs

The word “uncertainty” inevitably enters into every engineer’s vocabulary. Even in the most advanced disciplines, engineers must regularly make judgment decisions based on incomplete information. Take the structural engineer for example.

Structural engineering is probably two or three generations beyond the state of the art of fire engineering. The fundamental research literature and data needed to make sound engineering judgments are relatively sophisticated.

In practice structural engineers use a long tested performance-based approach called Load and Resistance Factor Design (LRFD) [2]. In simple terms the engineer estimates the “load” on the structure whether imposed by the forces of gravity, wind or earthquake. Then the strength of the structure is calculated (“resistance”). The goal is to design a structure which has a strength that exceeds the sum of the loads, or

$$\text{Building Strength} > \sum \text{Loads (dead loads, live loads, snow, wind, earthquake)}$$

Structural engineers have an arsenal of tools with which to perform LRFD analysis. On the load side of the equation estimates can be made using widely published charts and tables which characterize expected field exposures. These tools give the engineer good data with which to forecast the live loads created by building contents, prevailing wind loadings, snow loads and earthquake magnitudes to be anticipated. This load data is essential.

Ample literature, charts and graphs are also available to provide strength estimates for the various common building materials such as steel, concrete and wood.

“Uncertainty” is the nemesis of performance-based fire safety design today. Other disciplines, like structural engineering, have made great strides toward compensating for unknowns in design decision making...whether those unknowns relate to the forces to be imposed on the building or its ability to resist those forces. In essence structural engineers, for example, underestimate the building strength and overestimate the loading forces through the use of generally accepted factors of safety. To illustrate, hypothetical factors of safety could be added to the LRFD illustration above as follows – where the building strength is reduced by 10% and the assumed loadings are increased by 50%:

$$(0.9) \text{ Building Strength} > (1.5) \sum \text{Loads (dead loads, live loads, snow, wind, earthquake)}$$

Some of the holes in performance-based fire safety design include a lack of credible and generally accepted references, charts, tables on:

- Dynamic fire loadings in actual buildings...heat, smoke, toxic gasses
- Safety factors for making loading assumptions – how much should the load be overestimated?
- Quantitative performance data for fire protection systems (the “strength” of the building)
- Safety factors to account for uncertainty in performance of fire protection systems such as structural frames, automatic sprinklers, fire detection and smoke control – how much should the impact of active and passive protection schemes be underestimated?
- Generally accepted methodologies for calculating load vs. strength of buildings... total system performance analogous to the LRFD methods in structural engineering

One may ask whether we fire engineers have gotten a little ahead of ourselves in implementing performance-based methods on such a wide scale with so many uncertainties looming in the background. For example as early as 1992 the building code of England and Wales was “performance-ized”, reducing the 307 pages of highly detailed specification requirements to 19 pages of vaguely stated performance goals [3]. Similar has happened in the US. Some have asked whether the sophistication of the science, engineering methods, published data and training of practitioners are mature enough to fill the vacuum left by specific, tangible requirements.

Social Needs

Using regulatory codes and regulations, civil society decides how safe it wants to be and how much it is willing to pay for the desired outcome. Public policymakers generally decide on the minimally acceptable safety goals which engineers must design against. Much work remains to be done to better facilitate this public safety objective, whether safety concerns center on the damaging forces of fire, earthquake, flood or windstorm .

In recent years the American regulatory community has made inroads toward helping public officials understand and adopt goals with respect to acceptable levels of loss. For example, the International Code Council (ICC) had developed tables and charts that portray acceptable levels of damage vs. building use type vs. severity of the loading. This is illustrated in Table 1, adapted from the ICC Performance Code for Buildings and Facilities [4]:

| Event Size (hurricane, flood, snowstorm, fire, earthquake) | Level of Damage Tolerated | | | |
|--|-----------------------------------|------------------------|-----------------------|---|
| | Minor Storage Facility | Business Office | School, Clinic | Large Surgical Trauma Center |
| Very Large | SEVERE | SEVERE | HIGH | MODERATE |
| Large | SEVERE | HIGH | MODERATE | MILD |
| Medium | HIGH | MODERATE | MILD | MILD |
| Small | MODERATE | MILD | MILD | MILD |

Table 1. Socially Tolerable Levels of Damage

The idea that the acceptable severity of damage in a hospital vs. an office has always been implied in our codes and standards, but this has historically not been quantified. Much work remains to be done in this important area for both the design of new buildings and the vulnerability assessment of existing facilities. This includes the need to:

- Better quantify performance goals in terms of acceptable loss
- Help public officials and private clients make informed acceptable loss decisions

Finally, it must be recognized that different societies (and even different cultural/socio-economic regions within a society) have different levels of acceptable and affordable fire safety performance. Public officials in more developing regions of the world simply cannot cope with the technology, codes, standards and costs of the more developed Western world. If modern codes and practices are not simplified and adapted to local cultures, those cultures end up going without the benefit altogether.

A recent *NFPA Journal* article by Lisa Braxton [5] gives an example of adaptation in a related non-technical field. The article cites an enormous safety problem in South Africa, noting over 40% of South Africa's 23 million people use paraffin stoves for heating and cooking. Fires in these exceptionally dangerous devices result in some 3,000 deaths annually...almost exclusively in the nation's poorest shanty towns.

The National Fire Protection Association Center for High-Risk Outreach assisted local leaders in South Africa, including on-site facilitation from Ed Kirtley, then fire chief of Guyton Oklahoma and chair of the NFPA Committee on Professional Qualifications for Public Fire and Life Safety Educator [6]. In the words of Chief Kirtley... "Third World countries that want to do something with fire safety are at the mercy of what First World countries have developed...so they're trying to do something [with fire safety education] that isn't culturally appropriate".

The same thing is true in the technical areas of codes, standards and fire engineering. Less developed countries do not have the resources or talents to follow modern Western world best practices. And neither do they have the sophistication with which to interpret, adapt and set priorities that will fit within the local paradigm. The “modern Western World” can do more to:

- Produce tools to help public officials in less developed regions of the world take advantage of current fire safety know-how in a manner that is compatible with local cultures and resources
- Assist with training and education strategies adapted to local cultures

Summary

Fire engineering has made remarkable progress over the past generation. Yet, despite our technological accomplishments much is yet to be done, including the following:

- Filling knowledge gaps in performance-based analysis and design
- Gaining best practice consensus on analytical methodologies
- Gaining best practice consensus on safety factors for dealing with uncertainty
- Improving the database of fire-related loadings in actual buildings
- Funding for university scholars
- Creating effective tools to help public policymakers set acceptable damage goals appropriate to their cultural context
- Providing training and assistance to less developed regions and cultures

References

- [1] Lucht, D.A. (Editor), “Making the Nation Safe from Fire: A Path Forward in Research”, The National Academies Press, Washington, DC, 2003
- [2] Kennedy, D.J.L., “Limit State Design of Steel Structures in Canada”, *Journal of Structural Engineering*, ASCE 110, February 1984
- [3] “Building and Buildings”, *The Building Regulations* 1991, No. 2768, HMSO London
- [4] Performance Code for Buildings and Facilities, International Code Council, 2006
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- [6] “Professional Qualifications for Public Fire and Life Safety Educator”, NFPA 1035, National Fire Protection Association, 2005.