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SFPE PERSPECTIVES ON PERFORMANCE-BASED FIRE SAFETY DESIGN

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ABSTRACT

Performance-based codes* and fire safety engineering** methods are the focus of significant discussion, research, and development activities worldwide. In many respects, this is a result of the large increase in knowledge in the areas of fire science and engineering over the past twenty years and of the societal and economic pressures to provide an acceptable level of fire and life safety in buildings at a reasonable cost. While several countries have begun to use, or are developing, performance-based codes, many people have concerns about the availability of proven engineering and design methods for use within a performance-based code framework. Although many of the countries that are developing performance-based codes are also developing performance-based engineering and design methods, the codes are preceding the engineering methods, and the engineering methods have gone essentially unvalidated. There is also concern about the availability of qualified fire safety engineers to undertake performance-based designs, the availability of qualified authorities to review performance-based design, and the issue of liability related to performance-based design. The Society of Fire Protection Engineers supports the development of performance-based codes and fire safety engineering methods. However, the SFPE also recognizes that practical barriers to the widespread acceptance of performance-based fire safety codes and engineering methods exist in the United States, and in other countries of the world, and is working in several areas to address the needs of the fire safety engineering community in this regard.

INTRODUCTION

There are a number of interest groups that comprise the global fire and building community. These include building owners and managers, architects, engineers, construction contractors, building officials, fire officials, product manufacturers, the insurance industry, and more. The Society of Fire Protection Engineers represents one segment of this community: fire protection engineers. As such, the SFPE represents the body of knowledge of fire protection engineering, and is an advocate for the profession and its technology within the greater community. In this role, the SFPE advocates the proper use of fire safety engineering principles and supports the implementation into practice of emerging fire safety engineering tools and methodologies that can benefit the greater fire and building community.

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* The term 'codes' will be used to cover the broad areas of codes, standards and regulations.
** The terms fire safety engineering, fire protection engineering and fire engineering are used interchangeably throughout.

Given this position, the SFPE finds itself becoming increasingly involved in discussions and projects related to performance-based codes and fire safety design methods in the United States and around the world. The reasons for this are clear: for a performance-based system to be effective, there must be acceptable engineering practices available to support performance-based codes, and there must also be acceptable engineering tools and methods available to support the engineering practices.

THE INTERACTION OF PERFORMANCE-BASED CODES AND DESIGN METHODS

The interaction between performance-based codes and design methods can be viewed as a single, *performance-based system* with three major components:

- The Code, which reflects society's expectations of the level of health and safety provided in buildings (e.g., requirements for acceptable access, egress, ventilation, fire protection, electrical services, sanitary services, etc.);
- Engineering Practices, which describe acceptable processes and procedures for complying with the requirements of the Code (e.g., acceptable design approaches); and,
- Tools and Methodologies, which provide the means for undertaking designs in accordance with Engineering Practices (e.g., equations, correlations, models).

If any one of the three components is missing, the system is considerably weakened, and in some cases, may not function (e.g., the availability of an engineering tool without guidance on its applications and limitations limits the effectiveness of the tool).

To support the development of the overall performance-based system, the SFPE is focusing on the two fire safety engineering areas: development of engineering practices (engineering practice documents) for use in fire safety design, and identification and evaluation of engineering tools and methodologies, developed by research and academia, that are intended for use in fire safety engineering practice.

To help place the engineering aspects of the performance-based system into perspective, the SFPE is also looking at how a performance-based system might be structured if implemented in the United States. This is important: the system may not work if the components are improperly aligned or out of balance (e.g., a performance-based code without engineering practices available to meet code requirements).

The SFPE is convening a focus group of leaders from the fire and building communities in the United States, supplemented with experts from around the world who have been active in the development and implementation of performance-based systems in their countries. The group will be given working concepts and definitions to use as bases, and will be asked to comment on items of interest and concern to them regarding the implementation of a performance-based system in the United States. Some of the working concepts and definitions that will form the basis for discussion are as follows.

PRESCRIPTIVE CODES AND PERFORMANCE-BASED CODES

In general, building codes describe how a building should perform under normal and adverse conditions (e.g., fire) in meeting the health and safety needs of the community.

Prescriptive codes describe the desired level of performance for health and safety through a set of minimum requirements that are generic by occupancy. Examples include occupancy-based spacing requirements for detectors or sprinklers, a specified fire resistance rating for an interior wall, or the maximum travel distance to an exit. While these may be appropriate for a general minimum, the true objective of a stated requirement in a specific design situation can be lost.

For example, one may know the maximum permitted travel distance to the exterior of the building, but not know the extent of smoke spread within a building before the last occupant is expected to have escaped. Thus, if the intended objective of the travel distance restriction is life safety, it would be easy to state that the requirement has been met, but difficult to state that the objective has been met. By contrast, performance-based codes describe requirements for health and safety through a set of flexibly defined performance objectives and functional requirements. Examples include broad-based statements such as:

- the objective of this requirement is to safeguard people from injury from the effects of fire while evacuating a building, and,

- installation of an automatic suppression system intended to control the development and spread of fire shall be appropriate to the building use and characteristics, the fire hazard, the height of the building and the size of the fire compartment.

In this case, the solution is not prescribed in the regulations. Rather, it is the responsibility of the designer to demonstrate that the proposed design meets the health and safety needs of the community by meeting the performance objectives and functional requirements of the code. This demonstration of compliance can be accomplished through the application of either deemed-to-satisfy (prescriptive) solutions or performance-based design solutions based on accepted engineering practice (with prescriptive-type requirements for test, installation and maintenance).

ENGINEERING PRACTICES AND PERFORMANCE-BASED DESIGN

Engineering practices (or engineering practice documents) are generally considered framework or guidance documents that establish appropriate process and procedure for the undertaking of an engineered approach to a problem. Where only a small number of analytical procedures exist, they may be incorporated into the document, otherwise they will likely be referenced. One example of an engineering practice might be an engineering practice for the calculation of structural fire resistance. One might expect such a document to identify the analysis process and include material properties, dimensions and orientation, failure temperatures, effects of protective coverings, and possibly analytical procedures as well. If properly developed, this document should provide all of the necessary information to undertake a calculation of structural fire resistance.

To promote the development and use of engineering practice documents for fire safety engineering, the SFPE has formed a task group to develop engineering practice documents. The goal for the Engineering Task Group (ETG) on Engineering Practices is to begin developing a range of engineering practices for the fire protection engineering community. These documents will help fire protection engineers and regulatory officials understand the process to be followed, the engineering tools and methodologies available for use within the process and how to apply the engineering tools and methodologies with confidence. The first task of this group is to develop an engineering practice document on thermal radiation hazard calculations. A number of other fire safety engineering topics will be addressed in the future.

A document that outlines a performance-based approach to fire safety design can also be considered an engineering practice. A performance-based approach to fire safety design is an engineering approach to fire safety design based on (1) agreed upon fire safety goals, loss objectives and performance objectives, (2) deterministic and probabilistic evaluation of fire initiation, growth and development, (3) the physical and chemical properties of fire and fire effluents, and (4) a quantitative assessment of design alternatives against the loss and performance objectives.

Although a performance-based approach can be undertaken with or without the presence of a performance-based code, a performance-based code must reference at least one performance-based design approach, or engineering practice, to outline the process and procedure for complying with the requirements of the code. This is necessary because a performance-based code may contain only functional objectives and performance criteria, and likely does not contain detailed requirements as are present in a prescriptive code. Therefore, without the requirements of a prescriptive code to follow, an engineering practice document will assist the designer in identifying critical components of the design process which should be considered. The SFPE is currently attempting to identify the fundamental components of such an engineering practice, or framework for performance-based fire safety design, for application within the United States.

ENGINEERING TOOLS AND METHODOLOGIES

Fire safety engineering tools and methodologies encompass those equations, correlations, models and procedures used for engineering analysis and prediction of fire and fire related phenomena. Computer models used in fire and life safety analysis and design, for example, are considered fire protection engineering tools. So too are many of the equations and correlations found in the SFPE Handbook of Fire Protection Engineering. The difference between an engineering practice and engineering tools and methodologies is that an engineering practice provides the process and procedure to solve a global problem, and tools and methodologies are used to solve components of the global problem in accordance with the engineering practice.

For example, to estimate the available time for safe egress from a particular building, one might well undertake a process that includes determining building characteristics and features, fuel loading and arrangement (contents, interior finish, etc.), determining occupant characteristics, developing performance criteria (e.g., what renders the egress path unsafe), developing potential

fire scenarios, evaluating protection alternatives and evaluating evacuation factors. A process such as this would be well-suited to an engineering practice for evaluation of safe egress times.

Within this process, it will be necessary to perform a number of specific analyses, such as estimation of fire growth and spread, estimation of smoke production and propagation and estimation of fire detector activation. For these analyses, specific tools, such as computer fire models, and methodologies, such as those outlined in the SFPE Handbook for estimation of fire detector response to a growing fire, may be applied.

The first step that the SFPE has taken towards evaluating engineering tools and methodologies is the formation of an Engineering Task Group on Computer Model Evaluation. The goal for the ETG on Computer Model Evaluation is to evaluate computer models, intended for use in fire safety engineering, on their applicability, use and limitations within the evaluation and design processes. It will do this by stating the intended use of the model (from the model documentation) and evaluating the model and its documentation against its intended function. (It is not the intent to compare different models to each other.)

To minimize duplication of efforts in the area of developing evaluation methods for computer models, the ETG on Computer Fire Model Evaluation will apply various ASTM guides, i.e., ASTM E 1355, Standard Guide for Evaluating the Predictive Capability of Fire Models, ASTM E 1472, Standard Guide for Documenting Computer Software for Fire Models, and ASTM E 1591, Standard Guide for Data for Fire Models. Additional evaluation criteria and procedures will be used and/or developed as necessary. Sub-groups have been established within this ETG to look at procedures and protocol, documentation, test data for model evaluation, and algorithm evaluation. A framework for the evaluation reports is under discussion.

FIRE PROTECTION ENGINEERS AND FIRE PROTECTION ENGINEERING

Given that a performance-based system will be new to the United States, and that such a system will ultimately be more fire safety engineering intensive than a prescriptive-based system, the role of fire protection engineers in the performance-based system will likely increase. To help better clarify the role of fire protection engineers in the performance-based system, and why their role may be increasing, the following principles are currently being discussed within the SFPE:

- A performance-based system is based on the ability to engineer solutions to meet objectives.

- The use of engineering tools and methodologies in the analysis or design of fire safety measures to meet fire safety objectives constitutes the practice of fire safety engineering.

- The identification, evaluation and selection of fire scenarios, for use in an engineering tool, methodology or practice, that are based on fuel characteristics, loading and arrangement, compartment characteristics (e.g., volume), environmental characteristics (e.g., ventilation), occupant characteristics and situation related information, constitutes the practice of fire safety engineering.

- Fire safety engineering tools and methodologies should be utilized in the engineering of fire safety measures (performance-based or prescriptive) and reconstruction of fire incidents only where deemed acceptable by the fire safety engineering community.

- To attain "acceptable" status, fire safety engineering tools and methodologies should have been widely challenged in a peer-review process, or have been developed in or received positive evaluations in a consensus process among qualified engineers, educators and researchers, and have been validated in their ability to generate outcomes consistent with those claimed by the developer when used in accordance with the appropriate documentation. Safety and reliability factors that are included, or are required to be added, should be explicitly stated and based on accepted engineering theory, practice or statistics.

These are just a few of the concepts currently being discussed. Although the wording may change with additional discussion, the basic principles will likely remain in place: a performance-based system, in some form, is coming to the United States. A complete performance-based system requires a performance-based code, engineering practices, and acceptable engineering tools and methodologies, and a performance-based system requires qualified people to undertake performance-based designs. It will be interesting to see how these concepts evolve over the next few years.

SUMMARY

As in many other parts of the world, code development organizations in the United States are beginning to discuss the use of performance wording in their codes and standards. For such wording to become a reality in building and fire regulations, and for a performance-based system to see wide-spread acceptance in the United States, a number of practical fire protection engineering issues need to be addressed. The Society of Fire Protection Engineers recognizes this and is taking significant steps towards attaining their goal of identifying, evaluating and implementing into practice those engineering tools and methods necessary for fire safety design within a performance-based code framework in the United States. This includes helping to identify a performance-based system for the United States, outlining the needed components of a framework for performance-based fire safety design, developing engineering practice documents to support a performance-based system, identifying and evaluating engineering tools and methodologies for use in a performance-based system, and continuing to transfer knowledge and provide educational services in the area of performance-based fire safety engineering.

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Discussion

Ronald Alpert: I was curious as to where the financial resources are coming from for this very ambitious effort that you have outlined. I'm betting on a Swiss bank account.

Brian Meacham: As I have mentioned earlier, NIST has been very supportive of SFPE in these efforts. In particularly, with this focus group, the SFPE has a grant from NIST to study the technology requirements for implementation of a performance-based system in the U.S., and much of our support now comes from NIST. We would welcome future support from Factory Mutual Research.