LETTERS

Performance of Concrete-Filled Hollow Steel Columns

The *Journal of Fire Protection Engineering* Vol. 7, No. 3 included an article entitled *Performance of Concrete-Filled Hollow Steel Columns* by V. Kodur and T. Lie.

In the 19th century, hollow cast iron columns filled with concrete were fairly widely used. One trade name, *Lally Columns* was used generically.* It was soon learned that such columns would explode during a fire due to steam generated by contained moisture, and that it was necessary to drill holes through the cast iron column to vent the steam.

More recently, concrete-filled steel columns have been used in some semi-prefabricated homes. I have not seen any holes drilled in such columns. The Fire Chief of Scotia, New York, reported the explosion of such columns in a house fire.

The cited article gives examples of buildings using concrete-filled steel columns, but is silent as to any drilled holes. I am concerned that a phenomenon widely known in the 19th century has possibly escaped notice in the present generation, with potentially serious consequences.

In a letter Dr. V.K.R. Kodur answered my questions follows:

"The concrete filled HSS columns that were tested at the National Fire Laboratory were provided with four unobstructed holes, each not less than 12.7 mm in diameter through the steel hollow structural sections, so as to prevent bursting of the columns under steam pressure."

From a copy of the paper which described the tests more fully, the following was noted:
"...The vent holes need to be located in pairs at opposite ends of the column, 150 mm from the end of each length so that the orientation of the bottom two holes is perpendicular to that of the top two holes."

There is a larger question. It may not be enough to simply specify the drilled holes. Since their vital purpose will be unknown to the users of the building, it is possible that they might be considered a defect and sealed up, as one zealous inspector, ignorant of their purpose, ordered all the vent openings in tin clad fire doors to be sealed. Should performance- based codes include a manual prepared for each specific building indicating what must be done to insure that designed fire protection is not impaired by actions which may seem logical to the operator? Since, as Vincent Brannigan, J.D., has indicated, performance codes will require "cradle to grave" supervision, who will periodically check the manual against the actual conditions in the building?

Francis L. Brannigan
Author, *Building Construction For The Fire Service*

The authors respond

The authors wish to thank Francis and Maurine Brannigan for their interest in our work. The authors agree on the importance of drilling holes in concrete-filled HSS columns. In all the column tests carried out at the National Fire Laboratory, four unobstructed holes were drilled, each not less than 12.7 mm in diameter, through the steel section under steam pressure generated by the heating of entrapped water

*It is an article of faith among New Yorkers of the writers' generation, that "We tore down the 6th Avenue elevated, sold the steel to the Japanese, and they threw it back at us in WWII. In fact the columns were found to be concrete filled and could not be reclaimed economically.

in the enclosed concrete. The absence of these holes in concrete-filled steel columns can lead to disastrous consequences in the event of fire. Hence, small vent holes, with a minimum diameter of 12.7 mm, must be provided in the walls of the HSS in pairs at each floor level.

The authors also agree that, in North America, there are, at present, very few practical guidelines available for use by regulating officials, building owners, and engineers on the design and construction of concrete-filled HSS columns for fire resistance application. However, a design manual for concrete-filled steel columns is currently being developed at the National Research Council of Canada in collaboration with the Canadian Steel Construction Council. This will provide both design and construction guidelines for fire resistant construction of concrete-filled steel columns. The manual is expected to be released in 1997.

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Fire Modeling Tools for Fire Safety Engineering: Are They Good Enough?

I eagerly read the recent article, "Fire Modeling Tools for FSE: Are They Good Enough?" (Vol. **8**, No. 2, 1996, V. Babrauskas). Having written a similar paper recently,[1] I think that it's about time this message of limitations got more press. While I agree with the majority of the paper, there are a few things which are disturbing and a few points which I think need to be discussed.

The current state of fire modeling does <u>not</u> model fire. Only the effects of fire are modeled, *i.e.*, smoke, heat, gases, etc. The fire's characteristics are prescribed by the model user. We are a long way from truly modeling a fire and its growth on ordinary combustibles.

The author of the subject paper implies with an elitist attitude that there is great misuse in the input of data into zone fire models involving rate-of-heat-release, etc. While I somewhat agree with that, I would add that there are a lot of applications being done by qualified engineers, ("non-world-class" fire scientists) who understand many of the model limitations and approach fire modeling with a conservative attitude. T^2 fire inputs <u>can</u> be used with a good understanding of what it really means. All fire modeling applications should be appropriately bracketed, depending on the level of confidence involved. Many good papers involving fire model applications are now appearing in conference proceedings.

The author shuns the use of correlations in some fire model components as inadequate, e.g., flame spread. I believe such correlations as well as other creative techniques may be used with an understanding of their limitations, until proper scientific schemes can be developed, proven and integrated into the models.

The author states that the only successful credible fire modeling is conducted by "world-class" fire scientists working on litigation cases. That's ridiculous! We've seen several cases where such efforts have been wrought with mistakes and bad assumptions, and led to erroneous published results.

The author also implies that there is sort of a "crisis state" in fire modeling because the state-of-the-art doesn't provide the appropriate tools for all the performance-based design work going on or envisioned. I believe that fire modeling is in a positive state of evolution. As the demand for

1. Campbell, J., Mniszewski, K., "Precautions and Limitations in Fire Modeling," presented at the 1996 Department of Energy Fire Safety Conference, Oak Brook, IL, May 1996.

performance-based codes and applications grows, funds will be allotted for producing better tools. "World-class" fire scientists will advance fire science forward, whether a concerted effort is taken or not. And as with any other engineering tool, fire model abuse and misuse will continue as well, but on a higher plain.

Kim Mniszewski. P.E.
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The author responds

I agree with Mr. Mniszewski that correlational methods are an important tool in the fire safety engineer's tool kit. They are often the only tool available for attacking certain problems where the physics has not yet been studied in sufficient detail, or where the mathematics proved too difficult. However, I specifically excluded such techniques from the discussion of computer models for room fires. This is because one cannot strictly cross-compare solutions from correlational versus physics-based methods. The reason is that correlational approaches make sense only for interpolation within the domain of the experimental data points. A solution which has been produced on the basis of solving for the governing physics, by contrast, is not limited to any given domain of data--it is suitable for all circumstances that correspond to the mathematical formulation being solved.

With regards to Mr. Mniszewski's point that some designers are already using fire models, even without the availability of necessary physics components, I also agree. However, I view this more as a cause for concern than as cause for celebration. Again, Mr. Mniszewski identified the crux of the matter: "engineers...who...approach fire modeling with a conservative attitude." From what I have seen occurring in the profession, I do not find the conservative attitude to prevail. One can readily recognize the motivation: the designer usually takes a performance-based approach in the interest of saving his client money. Now, saving the client money is fine, if one can make sure that the designer understands enough of fire science to be able to make assumptions and approximations which actually are conservative. But as the wording in some of our fire standards now recognizes, "fire is a complex phenomenon." Indeed, the reason why some important features are absent from today's models is that even university professors and specialist researchers find the phenomena difficult to capture. Thus, while there is no doubt that design practitioners are providing estimates to fill in the holes in the models, there is no basis for assuming that these estimates are, in fact, conservative.

Finally, I wish to point out that there are two solutions to the present mismatch of model capabilities against designer needs: accelerate the development of the models, or slow down the use of performance-based designs. I sincerely, hope that we see the former and not that the latter.

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More on "Fire Modeling Tools"

The recent paper by Dr. Babrauskas (*Journal of Fire Protection Engineering*, Vol. **8**, No. 2), is extremely interesting, and contains little, if anything, I would disagree with. Yet it gives a negative message, open to the interpretation that we cannot make progress in fire safety engineering (FSE) until the institutions of the world get their act together and produce a great deal more work. However, we know that means "jam tomorrow -- but never jam today."[1]

Babrauskas asks if the fire modeling tools for FSE are good enough. The answer is, of course, "no." However, we can say errors using inadequate models are much less than those using no models at all (to paraphrase Babbage, who was referring to data).

Babrauskas says, and I quote: *"All of the*

FSE-based approaches presume our routine capability to numerically preduct fire behaviour." Designers do not need to make this presumption becuase that kind of prediction is not asked of them. Their responsibility is to determine what measures are needed to give a reasonable standard of protection. For example, the standard fire resistance test does not predict fire behaviour in a building, but it is possible to select a fire resistance rating for a particular building which will be found to give a satisfactory performance in practice. What is important is that the fire protection engineer (FPE) selects an appropriate model. For example, the hydrocarbon fire resistance test may be more appropriate than the standard test for some applications. Of course, if the main interest is in fire spread by radiation, then a model which incorporates temperature explicitly will be more useful than the "heat dose" model provided by fire resistance tests. In the selection of models, the FPE does not need to use awareness, which is a different kind of prediction. By awareness, I mean that the FPE must seek to identify aspects which might be critical to fire safety and model them accordingly.

In the design process, a model is more likely to be used as an aid to judgement than as a prediction. It is here that design differs from litigation or research, where a scientific need to understand exactly what happened is paramount. The numbers produced by a spreadsheet do not describe the safety measures needed, but give an assessment of the significance of various effects and assumptions. The FPE is not working in a vacuum, but within a culture of existing practice based on prescriptive codes. In proposing variations from existing code requirements or in designing for circumstances outside those covered by the code, the FPE at the moment almost inevitably argues on the basis of equivalence.

The further a design is from the prescriptive code, the more conservative the design becomes, and that is as it should be, until we have more knowledge. Accordingly, the models which the FPE selects generally show that buildings designed to the existing codes are not safe. If we assume, however, that the codes do give a reasonable standard of safety, which parts are important? We do not yet know, so we have to be careful with our variations. The corollary is, that even if we believe that the FPE has misused a model, we cannot state with confidence that the resultant design, though not code compliant, will be unsafe!

My own proposals are first, that for FSE designs an agreed procedure should be established for the selection of models, data input, the reporting of results, and the conclusions therefrom. Such a procedure has been adopted in Australia,[2] based in part on the draft British Standard.[3] In this way, perceived problems associated with the choice of, for example, heat release rate can be discussed so that a conservative model is chosen to compensate for uncertainties.

Secondly, the international bodies could cooperate in a study of what the existing codes do and which are the important features. This will need more effort than can be provided by any single body. The approach outlinbed by Professor Magnusson[4] at the International Conference on Performance-Based Codes seems to be what is needed.

Thirdly, we need more information on the reliability of fire protection measures, to complement a model-based approach. (Perhaps a publication of the estimates of reliability would also stimulate further efforts in the manufacturing and maintenance sectors.) Such information could, I believe, be assembled internationally. For the purposes of FPE, it is unlikely that national variations will be significant.

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1. Lewis Carroll, *Through the Looking Glass*.

2. *Fire Engineering Guidelines*, 1st edition, Fire Code Reform Centre, Sydney, March 1966.

3. *Draft Code of Practice for the Application of Fire Safety Engineering Principles to Fire Safety in Buildings*, Document 9413403340, British Standards Institution, London, June 1994.

4. Sven-Erik Magnusson, "How to Derive Safety Factors," International Conference on Performance-Based Codes and Fire Safety Design Methods, 24-26 September 1996, Ottawa.