

# Performance-based fire safety engineering

An on-going BRANZ and University of Canterbury research project will provide the tools necessary to keep New Zealand at the forefront of performance-based fire safety engineering.

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**S**erious fires in New Zealand buildings are rare and fatalities even rarer, supporting the building industry view that fire engineering is carried out in a professional manner by competent practitioners.

For simple building designs, the Department of Building and Housing compliance document C/AS1 provides comprehensive guidance for achieving fire safety.

For more complex buildings that go beyond the scope of C/AS1, specific fire safety engineering designs require a greater degree of engineering judgement. This is the focus of a collaborative research project between BRANZ and the University of Canterbury. The project began in October 2007 and is scheduled for completion in June 2012.

## Start by determining design fire(s)

The starting point for any specific fire safety engineering design is the 'design fire'. While structural engineers start their building design with structural loadings using the 'Loadings Code', AS/NZS 1170 *Structural design actions*, and know exactly what loads to design the building to withstand, fire engineers don't have the same starting point.

Design fires are estimates of scenarios that fire engineers consider appropriate for the particular building occupancy. They must take into account:

- where the fire starts
- what the fire's fuel is
- how quickly the fire will grow
- how much smoke and toxic byproducts will be produced
- where and how quickly these spread around the building.

Fire engineers therefore need to exercise engineering judgement in determining what design fire, or series of design fires, should apply to a specific building design. This inevitably means there will be subjectivity and inconsistency between designs for similar buildings. Officials who review the building design face similar inconsistencies.

## Using computer fire models

In carrying out specific designs, fire engineers will usually use computer fire models that predict the impact of a fire throughout a building. Hence, the building and its fire safety features – detectors and alarms, sprinklers, fire rated construction – can be designed to ensure that occupants can safely escape in the event of a fire breaking out.

These computer models may have complex calculation algorithms and produce impressive graphics, but the model is still only an approximation of what will actually happen in a real fire.

A feature of all of the commonly used computer fire models is that they are deterministic. This means that a single value is assigned to each input variable at the start of the computer simulation process, and single value outputs are produced at the end. However, the calculation process takes no account of the uncertainty or variability in the input values, so the likelihood of the resulting conditions occurring is unclear.

For example, if an average value is assigned to each input parameter, the resulting output value(s) will also be an average. The conditions would be exceeded 50% of the time, that is, half the building occupants may die in a fire. That isn't a desirable life safety outcome. If a worst-case maximum value is used in the modelling instead, a conservative and expensive design will result – another undesirable outcome.

In a performance-based environment, the key is to find the right balance between conflicting extremes.

## Finding the right balance

The aim of the current research project is to produce a non-deterministic, or probabilistic, computer design tool, so that risk-informed decisions can be made about life safety in buildings.

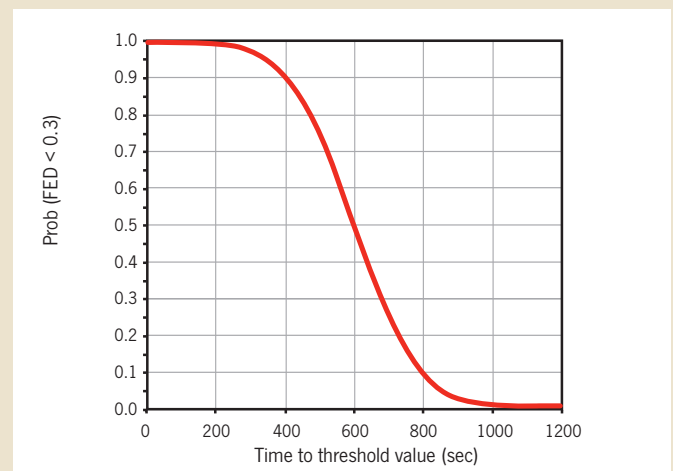


Figure 1: Example of the new model using Monte-Carlo simulation. It shows a 90% chance that the CO concentration will not exceed 0.3 at 400 seconds.

The resulting design tool will assign a probability distribution, or a weighted value, to key input parameters of the design fire as well as to the reliability and effectiveness of sprinklers, detectors and so on. The computer calculation procedures will then repeat the process over and over again for the whole range of values of the probability distribution – a procedure known as Monte-Carlo simulation. This means that the answer will not be a single value but will be a cumulative probability distribution.

### **New model indicates safety margins**

Consider a fire model output such as carbon monoxide (CO) concentration – the major killer in building fires. If the lethal threshold for CO – called the fractional effective dose (FED) – is 0.3, the deterministic model will indicate when this level is reached and how much time is available to safely evacuate building occupants.

Let's assume the model calculates 400 seconds. Figure 1 illustrates how the new model will display the result of the same calculation. Instead of getting the answer 400 seconds, the designer will be able to determine that there is a 90% chance that the CO concentration will not exceed 0.3 at 400 seconds.

It may seem as though the two models produce the same answer, but with the deterministic model, there is no indication of what the safety margin is. With the cumulative distribution output shown, designers and building officials can be much more confident that the design is safe.

### **A new era of safety design**

Future generations of the Building Code could contain probabilistic statements of building design, similar to this example. The Department of Building and Housing is in the process of developing a stepping stone towards this longer-term objective with its proposed fire safety design framework, which provides specific guidance and quantification of fire safety performance standards.

This research project will provide the tools necessary to usher in a new era of fire safety design and continue to place New Zealand at the forefront of performance-based fire safety engineering internationally.

*The project is funded by the Foundation for Research, Science and Technology and the Building Research Levy. ◀*