BEFORE THE ALARM SOUNDS

Fire, egress models allow building design to move beyond applicable code requirements

BY STEVEN STREGE

With the advancement of computers, mathematical models have emerged to aid engineers and architects in the design of safe buildings. A prime example of this is in the area of fire safety.

Fire protection systems and egress components of a building must meet prescriptive fire code requirements, unless it can be demonstrated that the building design meets an equivalent or higher level of safety through a performance-based design. This option was first introduced 15 years ago in the 2000 edition of the National Fire Protection Association's (NFPA) Life Safety Code, known as NFPA 101.

FIRE RISK ASSESSMENT

Computer models provide an invaluable tool to evaluate the level of safety provided by a performance-based design.

Fire protection engineers use two types of models: Fire models and egress models. Fire models are used to predict the growth of a fire (producing heat and smoke) and its impact on the building's environment. Egress models are used to predict the movement of people and how long it will take to evacuate the building or space within the building.

Fire and egress models are often used together to assess the environmental condition that will develop from a fire and the time required to evacuate occupants to an area of safety before an untenable condition occurs due to heat and smoke. For example, fire and egress models are typically used in smoke control design via a tenability analysis. A modelling analysis of a proposed smoke control system, for example, may show occupants will be exposed to light (yet tenable) smoke during an evacuation event. Conversely, under prescriptive codes, exposing occupants to any level of smoke is not permitted since the properties of the smoke are unknown and, therefore, worst-case conditions must be assumed.

TYPES OF MODELS

The most advanced type of fire model available today is a computational fluid dynamics (CFD) model. A CFD model divides a room or volume of interest into small cubes, called cells. The CFD model may consist of thousands or even millions of cells, depending on the size of the room and the desired resolution of the model output. At the interface of each cell, heat and mass transfer equations are solved at very short time scales (fractions of a second) resulting in millions of calculations for a given simulation.

The potential uses of CFD models are almost limitless, however, these models are very computationally demanding and often require significant time (days, even weeks) to complete a simulation. Due to the computational demand and number of cells involved, it is not practical to model an entire building.

If a fire protection engineer needs to consider the entire building or very large volumes, zone models may be better suited. Zone models divide a building volume of interest into one or two regions. For simple zone models, the environmental conditions (for example, temperature and smoke concentration) within a given zone are considered uniform. Other zone models will divide a space into two regions: a hot, upper layer (where heat and smoke develop) and a cool, lower level.

Compared to CFD models, zone models are significantly less computationally demanding; however, the resolution of the output is much lower. Zone models allow the engineer to analyze the entire building and produce results quickly — within seconds to hours. The quick simulation time also allows the engineer to evaluate the impact of small changes to the building design or conduct a sensitivity analysis of input assumptions.

Heat transfer models consider the thermal properties of a material and the thermal exposure to that material to predict the time-temperature profile throughout the material. For example, heat transfer models can predict the time-temperature profile through a reinforced concrete wall.

Egress models are generally used to predict how long it will take a group of

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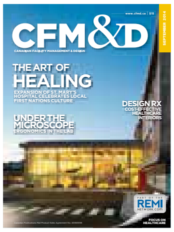

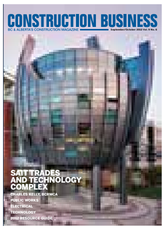

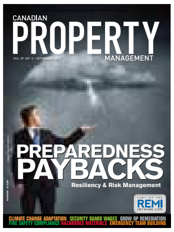

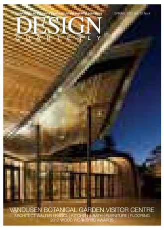

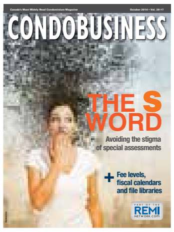

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5255 Yonge Street,Suite 1000, Toronto, ON M2N 6P4 people to evacuate a building or space within a building. They consider how a person's movement will be impacted by a building's geometry as well as other occupants. Most egress models incorporate occupant flow-density relationships that are well-defined in the Society of Fire Protection Engineers' (SFPE) handbook.

There are more than 30 egress models available on the market today, some of which are more sophisticated than others. For example, there are egress models that allow engineers to adjust an individual's physical dimensions (such as height and shoulder width), physical movement (such as travel speed and agility), physiological parameters (such as "drive" and "patience") and group behaviour (such as family members waiting to exit the building together).

BENEFITS TO BUILDING OWNERS/MANAGERS

Computer models, coupled with an experienced fire protection engineer, provide a wide range of benefits to building owners/managers. These include system cost savings and greater flexibility in building design, which otherwise would not be permitted by prescriptive codes.

CFD models can be used to reduce fan sizes needed for atrium smoke control by predicting the smoke conditions (temperature, visibility and carbon monoxide levels) from a fire using a tenability analysis.

Heat transfer models can be employed to determine if fireproofing exposed steel is needed in high ceiling spaces, such as atriums. Heat transfer modelling can also be used to ascertain the adequacy of fire barriers or guidance on the level of protection or thickness of a barrier necessary to meet applicable standards. The heat transfer analysis can be used to quickly assess the response of multiple fire barrier designs to many different fire exposures. This provides a significant advantage over a fire test in terms of cost and time.

Zone models can be used to help balance complicated smoke control systems involving multiple active systems (such as stairwell and elevator hoistway pressurization systems). They can also be employed to consider how wind and outside temperatures (for example, stack effect) will impact a smoke control design.

Egress models can be used to evaluate the impact of code-deficient egress conditions, such as excessive travel distances, dead end corridors, and issues with egress capacity and number of building exits. Egress models can also be employed to evaluate high-volume merging occupant flows during an evacuation event, which are difficult to assess using standard hand-written engineering calculations. High-volume merging flows are commonly observed at stadiums, airports, subways, convention centres, casinos and highrise buildings. ■

STEVEN STREGE IS A SENIOR ENGINEER AT JENSEN HUGHES. STEVEN HAS 15 YEARS EXPERIENCE AS A FIRE PROTECTION ENGINEER, SPECIALIZING IN SMOKE CONTROL DESIGN, TESTING AND EGRESS MODELLING. HE IS CURRENTLY A MEMBER OF THE GROUP TASKED WITH UPDATING THE SOCIETY OF FIRE PROTECTION ENGINEERS' (SFPE) ENGINEERING GUIDE TO HUMAN BEHAVIOUR IN FIRE.