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Canadian Building Digest

Division of Building Research, National Research Council Canada

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Strategies for Improving Visibility in Fires

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F.R.S. Clark

Abstract

The designer can help to assure that the modern building is safe from the sight-obscuring effects of smoke from fires by knowing the amount of smoke that can be generated and by knowing how to provide for efficient exit signage.

Introduction

Smoke causes more loss of life in building fires than any other element. One reason is that people become trapped when they cannot find familiar landmarks and subsequently succumb to toxic gases, heat or flames. The size of fire that can produce a life-threatening situation is remarkably small: the combustion of even a single, ill-chosen seat cushion can generate enough smoke to obscure an exit sign on the far side of a large room. Controlling smoke density by appropriate choice of the materials used in buildings and optimizing the visibility of exit signs can reduce the dangers of smoke.

Smoke Production

The amount of smoke produced in a fire depends on the type and amount of material available for burning and on the conditions under which burning takes place. Choosing materials that generate little smoke can help to avoid potentially hazardous, vision-reducing conditions.

Current tests for smoke evolution rarely permit comparison of the actual amount of smoke that might be expected from various materials. Instead, the density of smoke generated by a known amount of test material is compared with that generated by the same amount of other materials. This is related to the amount of light that can pass through a smoke-filled space in comparison with the amount passing through the same space in the absence of smoke.

Building codes in Canada have requirements that limit smoke-generating potential by controlling the materials used in buildings, particularly high-rises. Examples of these requirements may be found in Sentence 3.1.11.6.¹ of the National Building Code of Canada. For the purposes of the Code smoke generation is tested by means of the tunnel flame spread test.² Smoke classifications express the performance of the specimen in relation to that of red oak, which has a classification of 100. The Code sets minimum acceptable classifications that range from 25 for walls of exit stairways to 500 for floors of corridors and marketing of products, as well as other test procedures that work on the same principle.

The most common of these is the smoke chamber test³ developed at the U.S. National Bureau of Standards (NBS). It requires far less material than the tunnel test (specimens are only 65

mm square, compared with 7 m long), allowing more rapid and economical testing. Results are expressed as specific optical densities, figures ranging from less than 50 for leather or polycarbonate plastic to over 500 for polypropylene, rubber and hardboard.⁴

Burning area

The main problem in applying the results of current test procedures is that they usually take no account of the actual amount of material burned. Without this information it is impossible to gauge accurately the amount of smoke that will be produced. However, since the amount of smoke produced in a fire is approximately proportional to the burning area and the volume through which the smoke can be dispersed, the smoke density can be anticipated if one knows the volume of the room and the available burning area.^{5,6}

Conditions of burning

The amount of smoke that can be generated is strongly dependent on the conditions of the fire, i.e., on the amount of heat to which a material may be exposed, the ventilation, and the orientation of the material (vertical or horizontal). Generally, there are two broad types of burning: flaming combustion, and those like smoulder, which do not display flames. Smoulder, which is characteristic of fires in bedding, for example, often produces less smoke than the more familiar flaming combustion of wood.

If the air change rate of the space is ignored or if smoke is not distributed homogeneously in a vertical plane, estimates of the smoke peril may be exaggerated. Conversely, if burning is not restricted to the surface of materials, the possible smoke hazard may be underestimated.

Examples

A typical smoke analysis, in this case an analysis of the role of furniture in smoke generation in a room fire, can serve to demonstrate the utility of the approach.⁷ Consider first the effect of material selection. In a typical case, simply changing the textile covering of a chair can quadruple the amount of smoke generated by the contents of the room. An estimate of this kind also demonstrates that the smoke from carpets is far more important than that from drapery since there is usually much more material available to burn. Changing drapery material to a more flammable fabric leads to an insignificant increase in smoke hazard if the carpet remains the same.

Visibility through Smoke

Knowing the distance at which exit doors, signs, and egress routes can be seen is an important component of designing a safe building. This distance is a function of the performance of the human eye and the nature of the visual stimulus, particularly the luminance (brightness) of the visual target and its contrast against the general background. The presence of smoke between the observer and the target reduces visibility in a manner dependent on at least three factors: the density of the smoke, the distance from target to observer, and the presence of light from sources other than the visual target.

These effects were dramatically displayed during experiments designed to evaluate the performance of exit signs in smoke.⁸ In the absence of other lights in the test chamber, signs of conventional design were visible through 2-5 m of smoke of a lower density than that found in many fires. When additional illumination sources were introduced, visibility was substantially reduced. Just as fog particles scatter light from car headlamps on full beam, smoke particles scatter ambient light and absorb light from the target, reducing visibility at high ambient light levels.

It should also be recognized that loss of vision is by no means the only danger from smoke. The hazard is not completely described by the degree to which vision is obscured. Smokes are toxic, albeit to differing degrees.

Exit Signs

Exit signs are important indicators of evacuation routes in emergencies such as fires, particularly if the exit route is unfamiliar. Current requirements of the National Building Code (Subsection 3.4.5)¹ for exit signs were established on the premise that evacuation would occur before smoke could obscure the sign. Either internal or external illumination of the sign is permitted, although the lettering of the word EXIT (or SORTIE) must be of a particular size (depending on the illumination source) and the colour red must form part of the sign surface (although other contrasting colours may also be employed). The signs must be plainly visible, in direct line of sight, and well separated from other signs.

It has been demonstrated that it takes relatively little smoke to obscure exit signs or make them difficult to see. If it is assumed that signs may not always be adequate to guide occupants to a place of refuge, the designer must ensure that building occupants are not exposed to smoke. Some authorities recommend that one should never enter a smoke-filled space from a smoke-secure zone of a building. While this is excellent advice, people do sometimes find themselves exposed to smoke. In such cases the present requirements may not provide adequate indication of escape routes. A study by the Institute for Research in Construction⁸ identified some simple characteristics of exit signs that optimize visibility in smoke:

1. Exit signs should be as bright as possible. People taking part in the study consistently found it easier to see bright signs through smoke.
2. The number and location of signs should minimize the distance between observer and sign at all times. Transmission of light falls off with distance, so that apparent brightness also is diminished.

Placement

Low placement of signs on walls may increase visibility in the early stages of a fire. In some countries exit signs are always placed low on walls rather than above doors, as is customary in Canada, because smoke tends to travel along the ceiling when it mixes with hot, buoyant fire gases. As these gases cool, however, the smoke sinks and eventually fills the entire space. Smoke may also be dispersed evenly through rooms by forced ventilation systems and by the action of sprinklers activated by the fire. Under these conditions low placement of exit signs may offer little advantage. A preferred solution is to provide signage both high and low on walls.

Distinctiveness

Exit signs should be distinct from other light sources such as emergency lighting units. If light from exit signs reaches a building occupant through smoke, it may be scattered by the smoke particles to such an extent that it is not distinguishable from light coming from other sources. Signs are usually specified in a distinguishing colour to avoid such ambiguity. Provided no other source of light of the same colour is present, this may allow a sufficient degree of differentiation. Signs that flash when the alarm sounds offer advantages where colour differentiation may not be adequate.

Colour

Many countries have adopted green as the standard colour for exit indicators. Others recognize different colours so long as one colour is used consistently within a building. Both red and green exit signs are common in the United States, and red is almost universal in Canadian buildings.

Research has demonstrated that the actual colour of the exit sign is of secondary importance. The human eye is most sensitive to light in the yellow-green part of the visible spectrum, but other factors such as brightness, ambient illumination, and smoke density are usually more critical to visibility. Because Canadians are used to red exit signs, authorities have been somewhat reluctant to introduce other colours in case they do not convey the same message. However, the National Building Code now permits the use of other colours along with red.

Ambient lighting

Visibility of exit signs in a smoke-filled room is significantly improved if the ambient light is depressed to the low level specified in existing guidelines for emergency lighting in the National Building Code. Higher levels of lighting serve only to obscure signs because of scatter of light by smoke particles.

Emergency lighting

Care should be taken in the placement of emergency lights along exit routes. An exit sign and emergency spotlight in close proximity and facing in the same direction may be confusing in a smoke-filled atmosphere. A spotlight can obscure an exit sign by scattering light. Light-emitting apertures on exit signs, such as down-lights (apertures on the under side of signs placed above doorways), also degrade a sign's visibility through smoke. Many currently available exit signs are designed primarily for use in the absence of smoke, when such emergency lights and down-lights perform useful purposes.

The operating environment of many large buildings is now controlled automatically, especially under emergency conditions such as fire. The identification of emergency egress routes is a part of the information process that manages traffic flow, so that it is important that exit signs be treated within the overall strategy. In the presence of smoke it should be possible to automatically increase the brightness of exit signs and depress the level of ambient illumination to avoid the effects of scatter.

Sign design

At present, exits are indicated by signs that range from simple painted symbols on a wall to highly sophisticated and expensive powered devices. There are, however, opportunities to improve their performance for better visibility through smoke. It is possible to make exit signs much brighter, to make them flash during emergencies, or to design them with optimal lettering, sign contrast and information content.

Conclusion

Designers can reduce the smoke hazard in building fires in two ways. They can choose materials with a low propensity to produce smoke and they can maximize the visibility of exit signs by applying principles governing sign brightness and location, and ambient lighting levels.

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