Fighting Fire With...Other Things

In an effort to prevent the spread of fire within individual buildings and through cities, laws dictating the choice of certain building materials, construction assemblies, and urban configurations have developed. Fire behaves in complex ways and propagates according to the fuel, oxygen, and pathways available. To prevent a building from burning down, or to at least buy time to allow occupants to escape, designers have chosen nonflammable materials, employed means of protecting flammable components, delayed the effects of fire on noncombustible materials, and blocked pathways along which fire might spread. In addition to whether or not a building element will burn, designers consider how it behaves as temperature increases: does it melt? does it lose its ability to bear weight? does it fail gradually or catastrophically?

London recorded great conflagrations in 798, 982, and 1086. In 1189, to reduce the danger of fire, Fitz-Ailwyne's Assize was put into effect. London's buildings in the 12th century were built primarily of wood, with straw or reed roofs. The edict provided privileges to those who built stone houses with clay tile roofs, and has been referred to as the earliest English Building Act. In 1212, London suffered a great fire that prompted the limitation of various building uses and revisions to the Assize. The reinforced Assize strictly forbade any roofing materials but clay tiles, shingle boards, or lead. This did not, however, prevent houses with flammable wood structures from being built in the succeeding centuries.

In 1666, London suffered The Great Fire, which destroyed 80% of the city. In response, the city plan was redesigned by Sir Christopher Wren to provide a rational street system and further laws were enacted which governed the way in which buildings were built. Half-timbered buildings, which used highly combustible pitch to seal cracks, significantly contributed to the fire. Parliament's Act for Rebuilding the City of London stipulated that the exterior walls of all houses be built of brick or stone, with exceptions for incidental elements such as doors and window frames. Many of the principles contained in those edicts are still relevant and remain in force in some current building codes, for example, the requirement that party walls between buildings continue through the roof.

Until the 19th century, prescriptive strategies were used to avoid the spread of fire. To put out a fire, the choices were water or smothering. With the development of the steel building frame in the United States and Europe in the mid-19th century, a new, noncombustible building material came into play. The Chicago Fire of 1871, for example, prompted the largest early efforts to use recently developed materials—in this case, the steel building frame—in a strategic way to prevent losses by fire.

As technological advances permitted larger buildings to be built, escape provisions for crowds became a commonplace issue, especially, for example, in theaters or factories which experienced some of the most disastrous single fires. Slowing the effects of a fire allows more time for evacuation and firefighting, particularly during a fire's critical first hour. One strategy to slow the effects of fire is to protect various parts of a building with insulation. This strategy developed during the 19th century employed a structural technology known since Roman times: encasing steel in concrete. Mineral fiber made from spun molten iron slag and gypsum-based products are used as blankets or boxes to encase building elements. These materials remain inert in a fire, do not burn, and do not conduct heat readily. Above ~90°C, the chemical bonds in gypsum break down and release water, which cools the substrate. Cement- or ceramic-fiber-based materials sprayed on in liquid form and then left to harden are widely used to protect steel beams and columns. (Although these products are properly referred to as cementitious sprayed fire resistive materials, in the building world they are sometimes affectionately referred to as "flung dung.") Steel does not burn, but it does lose strength at high temperatures, causing collapse by drooping or otherwise giving way.

Intumescent materials, which were developed in the early 20th century, comprise another class of insulating fire protection. These materials are sprayed, painted, applied as putty, or wrapped in sheets onto the surfaces to be protected. Under exposure to high heat, intumescent materials foam up or "bloom." Once foamed, these materials harden and remain inert, exploiting the foam's air bubbles as an insulating cushion. As intumescent materials expand, they can also stop the spread of fire by sealing gaps and cracks. Intumescent paints and varnishes are used on a variety of substrates, including wood. When wood is kept from burning, the problems posed by its flammable surface and the loss of structure itself as it burns are delayed or prevented.

For even more action, we can turn to endothermic materials, which were developed at mid-century to protect electrical cables in nuclear power plants. These materials are often formed into blankets which are used to wrap steel structures and electrical wires. When exposed to intense heat, endothermic materials chemically absorb heat energy, keeping the substrate material comparatively cool. As the temperature rises, these materials also release chemically bound water to further cool the surface of the substrate. Endothermic foaming materials combine intumescent and heat-absorbing properties.

While shielding building components from fire comprises one strategy, another approach involves changing the makeup of building materials themselves. This can involve capitalizing on a material's inherent properties and extending them, or reducing a material's flammability. Wood, that most ancient of building materials, gets pulled into the mix. Wood products ranging from 2 × 4 lumber to engineered beams can be impregnated with fire-retardant chemicals. Although wood's flammability has always been its largest drawback, wood remains strong as it burns—and then fails catastrophically. If wood can be kept from burning, it retains its strength.

The most recent research into controlling fire danger has actively begun to re-incorporate prescriptive strategies. As techniques are improved for modeling the behavior of burning materials and further our understanding of the influence that building configurations have on the spread of fire, more precise solutions emerge. In this context, when a building's use and arrangement are examined simultaneously, opportunities arise for using fire-resistive materials most efficiently, eliminating a need for them where previously they might have been required by definition.

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FOR FURTHER READING: Donald W. Belles, "History and Use of Wired Glass in Fire Rated Applications," *Building Official and Code Administrator,* **29** (5) (1995) p. 16; J.M.L. Berna, "Introduction to the Technology of Intumescent Materials," *Mapfre Seguridad,* **11** (43) (1991) p. 94; MASTERSPEC, (The American Institute of Architects, Washington, DC, 1996); *Reinforced Concrete Fire Resistance,* (Concrete Reinforcing Steel Institute, Chicago, 1980); T.J. Shields and G.W.H. Silcock, *Buildings and Fire,* (Essex, 1987); "The Great Chicago Fire and the Web of Memory," online exhibit, (The Chicago Historical Society & the Trustees of Northwestern University, 1996); *The Encyclopedia Britannica,* 11th ed. (New York, 1911), vol. 10, p. 401, and vol. 16, pp. 959, 963.