which includes single-family and most low-rise multifamily residential buildings. Restricting the spread of fire is critical in reducing fire deaths and property loss. The overwhelming majority of U.S. fires are in residential buildings—apartments, hotels, and dwellings. Multi-family occupancies are particularly vulnerable because of the lack of physical separation between living units.

While most industrialized countries require a 2-hour fire wall between units, the United States does not yet do so, which results in greater loss of life and property each year. "One-hour" construction made of combustible materials and electronic detection and suppression systems provide a false sense of security based on unrealistic fire ratings and a reliance on poorly maintained, seldom-tested fire alarm and sprinkler equipment.

Fire regulations are concerned primarily with the safety of occupants, the safety of fire fighters, the integrity of the structure, and the reduction of damage. Construction must (1) limit the spread of fire within a building; (2) prevent fire spread to adjacent buildings; (3) maintain the integrity of occupant evacuation routes; and (4) allow for attack by fire services. The overall risk is reduced when non-combustible construction is used to construct or protect structural elements, and to divide a building into compartments for the containment of fire. Non-combustible masonry and concrete construction provide the highest level of protection through fire wall containment and structural integrity.

The degree of fire protection offered by masonry construction was recognized long ago. In 1212 A.D. an ordinance was issued by royal proclamation requiring that all alehouses in London be built of masonry. After the great fire of 1666, which destroyed most of London, King Charles II decreed that the walls of all new buildings must be of masonry. Modern masonry construction has an excellent performance record in fire containment, but non-combustible construction is not required in low-rise multifamily buildings, and standard fire ratings are misleading about the relative fire safety of different types of construction. "Fire-restrictive" construction with combustible materials is an oxymoron, and sprayed fireproofing on steel framing is subject to abrasion and delamination which leave the structure essentially unprotected.

8.4.1 Fire Tests

Fire properties of building materials are divided into two basic categories: *combustibility* and *fire resistance*. Masonry is classified as non-combustible. Fire resistance ratings are based on standard ASTM, NFPA, or National Institute of Standards and Technology (NIST) fire endurance tests. Under these fire test standards, walls, floors, roofs, columns, and beams are tested in a furnace under controlled laboratory conditions. For walls, one end of the furnace is sealed with the actual construction assembly being tested so that one side of the wall is exposed to the fire.

Specimens are subjected to controlled heat applied by standard time–temperature curve for a maximum of 8 hours and 2300°F. Wall assemblies must also undergo a hose stream test for impact, erosion, and thermal shock. Throughout the tests, columns and bearing walls are loaded to develop full design stresses. Within 24 hours after the testing is complete, bearing walls must also safely sustain twice their normal superimposed load to simulate, for instance, a roof collapse. Fire resistance ratings, generally in 1- or ½-hour increments, are assigned according to the elapsed time at which the test is terminated. The test is terminated when any one of three possible end-point criteria is reached: (1) an average temperature rise of 250°F or a maximum rise of 350°F is measured on the unexposed side of the wall; (2) heat, flame, or gases escape to the unexposed side, igniting cotton waste samples; or (3) structural failure occurs. The first two points concern only the containment of fire spread through the wall or section, while the third concerns structural failure and the consequent threat to life and property. Despite this fundamental disparity in the level of safety provided, each of the criteria carries equal weight in determining assigned fire ratings.

Fire ratings for "protected" construction with gypsum board or sprayed fireproofing are based on structural collapse. Fire ratings for concrete and masonry are based on heat transmission. The temperature on the unexposed side of a masonry walll rises 250°F while a "protected" wall collapses and allows the fire to spread, and yet the two assemlies are given an identical fire rating (*see Fig. 8-9*). Sprayed fireproofing can provide temporary protection for structural steel, but only if it is well adhered and intact. Because steel has high thermal conductivity, damaged fireproofing in one area can expose other ares to elevated temperatures. Inadequate thickness, abrasion, and delamination reduce the time it takes for a fire to weaken the steel and cause structural failure. Structural steel can lose 50% of its strength at temperatures as low as 1100°F. Open-web joists can collapse in less than 15 minutes if they are unprotected.

Masonry walls can withstand the impact of a hose stream after extended fire exposure, and are required to do so by ASTM E119, *Standard Method of Fire Tests of Building Construction and Materials*. Drywall assemblies generally cannot withstand the hose stream test and, in order to achieve their rating, a second test assembly may be substituted for the hose stream portion of the test. ASTM E119 allows this substitute wall to undergo the hose test after fire exposure for only half the rated time. During real fires, it is not possible to substitute a second wall. Firefighters who survived the World Trade Center collapse were reported to have said that "stairwell protected by concrtete... would have resulted in fewer casualties." A retired NYFD deputy chief added that NIST "should evaluate the substitution of drywall for concrete blocks when enclosing stairways and elevator shafts in high-rise buildings. Powerful hose streams collapse [the drywall]. They don't do that with the concrete." (As reported in "Clearing a Vertical Path to Safety," *Building Design and Construction Magazine*, September 2002.)

The structural integrity of a concrete or masonry wall is maintained far beyond the time indicated by its fire rating. Structural integrety is critical to the safe evacuation of occupants, and critical in maintaining access for fire fighters and equipment. A castastrophic collapse like that at the World Trade Center might be avoided with a structure of concrete and masonry and, even in a steel frame building, egress stairs can remain traversible for occupants and fire fighters if they are not built of gypsum board.

There are other discrepancies in standard fire tests which also affect the accuracy and credibility of the results. Furnace temperatures must be maintained at certain levels according to the elapsed time. As a result, the amount of fuel required for the test fire depends to some extent on properties of the test specimen. If the specimen itself burns, as it does in wood frame construction, it contributes to furnace temperature and reduces the amount of fuel needed to sustain the time–temperature curve conditions (*see Fig. 8-10*). In real fires, this means that combustible assemblies add to the fuel and therefore increase the intensity of the fire. If, on the other hand, the test specimen absorbs and stores heat from the furnace, as is the case with concrete and masonry, more fuel is required to maintain the test conditions. Although