Fire Safety with Portland Cement Plaster

By Walter F. Pruter

ABOUT THE AUTHOR

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More than any other of nature’s forces, fire has been a major hazard to life and property in buildings and structures. According to the National Fire Protection Association, billions of dollars are lost each year in the United States as a result of fire and explosions.

Fireproofing and construction of fire protective elements of buildings has always been a profitable part of the wall and ceiling contractors’ activities. Fire resistive walls and partitions to contain any outbreaks of fire from their place of origin have become requirements in all building codes. Likewise, protecting structural columns, beams, girders and trusses from possible fire damage by covering them with fire resistive materials has also been a healthy part of our contractors’ bid package. A premise which has played a major role in the overall fire risk control in a building is the extent to which fire resistant construction is used to protect structural elements and to compartmentalize the building. By dividing a building into sections with fire resistive walls, ceilings and floors, fires can be contained and prevented from spreading into full conflagrations.
Before any reasonable discussion of fire resistive construction can be undertaken, certain key terms must be defined. The concrete and masonry industries use these terms and they are widely accepted.

**FIRE ENDURANCE:** Fire Endurance is a technical term used to measure the elapsed time which an assembly continues to provide fire resistance under specified conditions of test and performance. As applied to elements of a building, fire endurance is measured by the methods and to the criteria defined by ASTM E-119, “Standard Methods of Fire Tests of Building Construction and Materials.”

**FIRE RESISTANCE:** Fire Resistance is a descriptive term used to describe the property of a material or assembly to withstand fire or give protection from it. As applied to elements of buildings, fire resistance is characterized by the ability to confine a fire or to continue to perform a given structural function or both.

**FIRE RATING:** Fire Rating or fire resistance rating is a legal term usually expressed in hours for an element in a building to maintain its particular fire-resistant properties. Model codes establish the required fire ratings for various building elements.

**TYPES OF CONSTRUCTION**

Building codes currently classify different types of construction according to the degree of fire resistance each one affords. In general, codes separate buildings into at least four types of construction with respect to fire resistance:

1. Fire Resistive Construction
2. Non-Combustible Construction
3. Ordinary or Exterior Protected Construction
4. Wood-Frame Construction

Usually these four types contain sub classifications, so there may be as many as ten types of construction defined and regulated by a particular building code. Figure 1 is a reproduction of Table No. 17-A from the 1988 edition of the Uniform Building Code listing fire resistive requirements for various building elements in different types of construction. Other model codes have similar tables, and it is recommended.
that you become familiar with the one applicable to work in your location. (See Table 600 in the SBCCI Standard Building Code and Table 401 in the BOCA National Building Code.)

Although the tables in these codes indicate required ratings as high as four hours for NON-COMBUSTIBLE Fire Resistive exterior walls in Type I and Type II buildings, this may be reduced for certain occupancies or where adequate horizontal separation is provided between adjacent buildings or a building and a lot line. Buildings equipped with automatic sprinklers sometimes are allowed a one hour reduction in fire resistance requirements.

For other types of construction, the required ratings for wall and other building elements can vary considerably as can be seen. In general these less fire resistant types of construction require either 2 hour or 1 hour fire ratings for exterior or interior bearing walls.

**The value of gypsum plaster and gypsum wallboard for providing protection from fire is well documented and widely recognized**

Exterior noncombustible, non-load bearing walls having no fire rating or fire resistive protection are generally permitted at locations where the walls are separated from property lines and adjacent structures by distances at least equal to that at which the code allows unprotected (plain glass) windows. Model codes vary considerably in their requirements for the separation distance at which openings should be protected and the area of any openings to be permitted.

**TYPES OF OCCUPANCY**

Different occupancies have different fire hazard characteristics which directly affect the safety of the building’s occupants. These characteristics do not particularly relate to the combustibility of the contents but concern conditions existing within the occupancy that could affect the relative ability of the occupants to safely evacuate the building in event of a fire. These characteristics involve such factors as the number of occupants, i.e., is it high or low. In the event of high occupancies such as crowds, audiences or assemblies, the danger of panic is added, so protected freedom of egress is important. Are the occupants likely to be asleep or awake during their period of occupancy and are they very young, very old, sick or infirm? All of these considerations, as well as others, enter into the proper requirements for public safety in the design and construction of buildings used for different occupancies.
Classification of occupancies should be based on the assumption that the occupancies in each group represent approximately equal fire hazards and of similar characteristics. Businesses for example can be conducted in office buildings, factories processing combustible materials and storage facilities among others. There would be no justification for grouping them together under a meaningless classification such as “business occupancy.” The wide divergence of fire hazards peculiar to each of the aforementioned examples could not be properly provided for in the fire protection regulations of the code. To cover the fire protective regulations more specifically, the code provides requirements for about seven or eight groups.

GROUP A. Assembly buildings or buildings containing assembly rooms, stadiums, reviewing stands and amusement park structures. Other types of rooms having an occupant load of 50 or more which would be considered assembly rooms would include:

1. Legitimate and Motion Picture Theaters
2. Church Naves and Lecture Halls
3. Cocktail Lounges
4. Gambling Casinos
5. Bus, Train, Airport Waiting Rooms

GROUP B. Any facility used for parking or repair of motor vehicles, and just about every other occupancy except for residential and hazardous uses. This includes offices, police and fire stations, retail stores, etc.

GROUP E. Educational facilities through 12th grade except for assembly rooms, etc.

GROUP H. Hazardous occupancies which process, handle, store or sell hazardous materials. This could include some repair garages utilizing welding and open flame operations.

GROUP I. Institutional occupancies including hospitals, nursing homes or other facilities where very young, sick or injured are cared for. Also jails and penal institutions.

GROUP M. Miscellaneous occupancies which aren’t usually occupied by people. Carports, small garages, sheds, etc.

GROUP R. Residential, including hotels, motels, apartment houses, convents and dwellings.

Each of these occupancy groups usually contains two or more sub classifications. The building height and maximum floor area is also restricted by the occupancy classification.

STANDARD FIRE TEST

Fire-safety requirements and regulations are based to a great extent on average performance, incidence, experience and circumstances. Most fire resistance ratings of Portland cement plastered walls, ceilings, columns and beams are based on fire tests conducted by the National Bureau of Standards, Underwriters Laboratories, and other recognized fire testing laboratories. Methods of fire tests are described in ASTM E119, “Standard Method of
Provisions of the ASTM E119 test require that specimens be subjected to a fire which follows the standard time-temperature curve shown in Figure 2.

Figure 2. Time-Temperature Curve

Under the E119 standard, the fire endurance of an assembly is determined by the time required to reach the first of any of the following three end points.

1. Ignition of cotton waste due to passage of flame through cracks or fissures in the surface.
2. A temperature rise of 325 degrees F (single point) or 250 degrees F (average) on the unexposed surface of the assembly. This is known as the heat transmission end point.
3. Inability to carry the applied design load or in other words, structural collapse.

Additional rating criteria for the fire endurance of a wall would include the ability to resist the impact erosion and cooling of a specific size hose stream. See table entitled “Conditions for Hose Stream Test” in Figure 3.

ASTM E119 also classifies beams, floors and roofs as either restrained or unrestrained. A restrained member is one in which the thermal expansion is restricted. Steel beams, welded, riveted or bolted to the framing members are generally classified restrained. In the case of bearing wall construction, open web steel joists or steel beams supporting concrete slabs, precast units or metal decking are considered unrestrained, as are all types of wood construction. Tables in ASTM E119 should be referred to when determining the presence of thermal restraint.

The three model building codes used in the United States, BOCA, ICBO and SBC, all require fire testing in accordance with ASTM E119, or analytical calculation based on ASTM E119 test data to satisfy all fire resistance ratings required by the codes. Recently approved analytical methods developed by the Concrete and Masonry Industry Fire Safety Committee have enabled those industries to obtain additional fire ratings at significant cost savings when compared to actual ASTM E119 fire testing. The results of many ASTM E119 standard fire tests were analyzed.

Research and development of data on steel and concrete strength at elevated temperatures, verification and modification of theory and the effects of restraining thermal expansion during heating all led to forming an accepted basis for analytical or calculation method of determining fire endurance.

Calculation of fire endurance of concrete and masonry members has progressed from pure research to practical structural design applications. Further refinements of analytical methods are going on now, aided considerably by computer simulations of concrete and masonry under fire test conditions.

Table P-3101.1 of Appendix “P” of the 1985 Standard Building Code is an example of the application of this effort (Figure 4). Tables in this appendix list acceptable minimum equivalent thickness of cast-in-place and precast concrete walls based on the type of concrete used. There are listings of 1 to 4 hours for siliceous, carbonate, sand, lightweight and lightweight concretes.

For walls consisting of two widths of different types of concrete there are other graphs indexing the fire resistance of varying thicknesses of different combinations. The accepted formula for determining these resistance ratings in minutes is also listed.

These tables and formulae are for concrete or concrete masonry walls without applied finish materials inside or out. Where a finish of gypsum wallboard or plaster (gypsum or portland cement) is applied to the concrete or masonry, there are tables of factors, depending on the type of concrete and the type of finish which may

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>Minimum Slab Thickness, in. for Fire Resistance Rating of 1 hr</th>
<th>1½ hr</th>
<th>2 hr</th>
<th>3 hr</th>
<th>4 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siliceous</td>
<td>3.5</td>
<td>4.3</td>
<td>5.0</td>
<td>6.2</td>
<td>7.0</td>
</tr>
<tr>
<td>Carbonate</td>
<td>3.2</td>
<td>4.0</td>
<td>4.6</td>
<td>5.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Sand-Lightweight</td>
<td>2.7</td>
<td>3.3</td>
<td>3.8</td>
<td>4.6</td>
<td>5.4</td>
</tr>
<tr>
<td>Lightweight</td>
<td>2.5</td>
<td>3.1</td>
<td>3.6</td>
<td>4.4</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Figure 3

Conditions For Hose Stream Test

<table>
<thead>
<tr>
<th>Resistance Period</th>
<th>Water Pressure at Base of Nozzle psi (kPa)</th>
<th>Duration of Application min/100 ft²(exposed area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 h and over</td>
<td>45 (310)</td>
<td>6</td>
</tr>
<tr>
<td>4 h and over if less than 8 h</td>
<td>45 (310)</td>
<td>5</td>
</tr>
<tr>
<td>2 h and over if less than 4 h</td>
<td>30 (207)</td>
<td>2½</td>
</tr>
<tr>
<td>1½ h and over if less than 2 h</td>
<td>30 (207)</td>
<td>1½</td>
</tr>
<tr>
<td>1 h and over if less than 1½ h</td>
<td>30 (207)</td>
<td>1</td>
</tr>
<tr>
<td>Less than 1 h, if desired</td>
<td>30 (207)</td>
<td>1</td>
</tr>
</tbody>
</table>
be applied to determine the increased fire resistance contributed to the finish. See Table P-3101.4A in Figure 5.

Since all three model codes now allow for analytical calculation of concrete and masonry members and assemblies, the building official can check fire resistance on paper. These provisions are found in Section 43-9 of the Uniform Building Code Standard, Appendix P of the Southern Building Code, and Section 1403.1.1 of the BOCA Code. (1403.1.1 references the CRSI and PCI documents on fire resistance calculation methods.) Not only does it help the plan checker review drawings, but these code sections are frequently used by state agencies and architects to specify requirements.

The Concrete and Masonry Industry Fire Safety Committee in Skokie, Illinois published a fire protection planning report in 1985 entitled, “Analytical Methods of Determining Fire Endurance of Concrete and Masonry Members—Model Code Approved Procedures.” It reflects years of research analysis and work with code authorities to gain recognition by the members of those industries. They are Brick Institute of America, Concrete Reinforcing Steel Institute, Expanded Shale Clay and Slate Institute, National Concrete Masonry Association, National Ready Mixed Concrete Association, Portland Cement Association and the Prestressed Concrete Association.

The plastering industry could well profit by the foresight and experience of these other industries. Everyone acknowledges that there is a shortage of acceptable test data particularly for fire resistive constructions utilizing Portland cement plaster.

The value of gypsum plaster and gypsum wallboard for providing protection from fire is well documented and widely recognized. Gypsum manufacturers and the Gypsum Association have conducted extensive tests over a period of 60 years or longer. Many of these test results have been collated and reproduced in useful lists and manuals such as the Fire Resistance Design Manual, now in its 12th edition, and updated every few years by the Gypsum Association.

Unfortunately, there are many situations where gypsum just can’t be used. For example, areas subject to moisture and weather exposure would cause the gypsum to deteriorate over a period of time. Portland cement plaster is the natural alternative, but there are not nearly as many fire tested Portland cement plaster constructions as there are gypsum.

The Foundation of the Wall and Ceiling Industry has undertaken to seek out and list those fire rated systems in which Portland cement plaster is a component part. [See related story, this issue.] Several references were researched to uncover this material. Because the Portland cement industry hasn’t done much in the way of testing, most of these constructions are many years old.

In spite of age, many of the constructions are recognized by code authorities and can be found in current editions of various building codes and publications of Underwriters Laboratories and Factory Mutual.

The compendium of systems, developed under the sponsorship of the Foundation of the Wall and Ceiling Industry, is the first attempt to set forth all those fire tests using Portland cement plaster. It will be updated in future editions but hopefully will be found valuable in its initial form.

**Fireproofing and construction of fire protective elements of buildings has always been a profitable part of the wall and ceiling contractors’ activities.**

Discussions with engineers at the Portland Cement Association and the National Concrete Masonry Association over the past several months confirm that there has been a scarcity of tests conducted with Portland cement
mortar, concrete and plaster. Both of these organizations now use analytical methods of determining fire endurance of concrete and masonry members.

The same factors which influence the fire resistance of concrete and masonry would also apply to cement plaster. These factors—thickness and aggregate type, thermal restraint conditions and temperature distribution through members—are included in the code approved methods for calculating fire resistance. As an industry we have never approached model code authorities to apply these methods to Portland cement plaster but should consider doing so.

This would be no small or inexpensive undertaking but considering the paucity of Portland cement plaster fire rated systems currently recognized by the codes, it should be given serious thought.

REFERENCES


The Foundation of the Wall and Ceiling Industry maintains the John H. Hampshire Memorial Research and Reference Library. You are invited to consult the library’s many valuable reference materials on a wide range of subjects: from general business management practices to technical data to building codes Library materials may be obtained on a free (except postage) 30-day loan basis.