fire protection planning report

BUILDING CONSTRUCTION INFORMATION FROM THE CONCRETE AND MASONRY INDUSTRIES

NO. 14 OF A SERIES

Separating the Structural Fire Resistance and Barrier Fire Resistance End Points

INTRODUCTION

ASTM E119 "Standard Methods of Fire Tests of Building Construction and Materials" is the recognized standard in the United States for determining fire-resistance ratings of building members and assemblies. The three model building codes in the United States, the BOCA Basic National Building Code, Standard Building Code (SBC), and Uniform Building Code (UBC), either adopt ASTM E119 by reference or, in the case of UBC, use it as the basis for developing a separate standard. Compliance with fire-resistance ratings specified in each of the model codes is based on testing in accordance with the procedures of ASTM E119.

ASTM E119 contains procedures for determining both structural and barrier fire-endurance end points. In the case of building elements, such as beams and columns, the standard requires the determination of a structural fire endurance only since these members are not intended to perform as fire barriers. For bearing walls, floors, and roofs which are required to serve as structural assemblies and may be required to perform as fire barriers, ASTM E119 specifies test procedures for determining both the structural and the barrier fire-endurance end points. However, the fire endurance of these assemblies is based only on the first end point reached. Thus a bearing wall, floor, or roof assembly reaching the barrier end point first may still have the capacity to perform structurally for a longer period of time.

For example, there are numerous assemblies, rated for one or two hours based on their barrier fire endurance, which may possess structural fire endurances of three or four hours or more. Since the fire endurance of these assemblies is based only on their barrier end point, the reserve structural capacity is not recognized.

There are many situations in buildings where assemblies need perform only one of these two functions. However, an assembly selected by an engineer or architect to meet a structural fire-endurance requirement may have achieved its rating based on fire-barrier performance and may actually possess significantly more structural capacity than is required. This results in the inefficient use of building materials, wasted construction time, and unnecessary construction and manpower costs.

This Fire Protection Planning Report examines the justification for distinguishing between structural and barrier fire resistances of wall, floor, and roof assemblies. Examples are presented to demonstrate that the difference between structural fire resistance and barrier fire resistance is already implied in the model codes, although it is not stated explicitly. Construction-cost savings that would result from separating structural fire resistance and barrier fire resistance are also demonstrated. Finally, changes to ASTM E119 and the model codes that are necessary to bring about the separation of structural and barrier end points are recommended.

Provisions of ASTM E119

ASTM E119 "Standard Methods of Fire Tests of Building Construction and Materials" specifies procedures and criteria for determining the fire endurance of building assemblies and structural elements. Test specimens are subjected to the standard time-versus-temperature conditions shown in Fig. 1.

Members and assemblies serving both fire-barrier and structural fire resistance functions such as bearing walls, floors, and roofs are rated based on the following performance or end-point criteria:

1. Temperature on the unexposed surface of the test specimen must not exceed an average rise of 250°F or a single point rise of 325°F.
2. The test specimen must not permit passage of flames or gases hot enough to ignite cotton waste material on the unexposed surface.

3. The test specimen must carry all applied loads and/or restraining forces developed throughout the test.

In some cases, test specimens must satisfy additional criteria. Walls achieving a rating of one hour or greater must resist the cooling, impact, and erosive effects of a water hose stream. In some structural steel floor and roof assemblies, as well as some reinforced concrete floor and roof assemblies, limits are placed on steel temperatures to ensure structural stability. Fire endurance is presently determined based on the limitations imposed by any one of the three primary end-point criteria stated above, or the additional criteria related to steel temperatures or the hose-stream test.

Criteria 1 and 2 above form the basis for determining the barrier fire resistance of an assembly. Criteria 3 and additional steel temperature limitations combine to form the basis for determining structural fire resistance. The first end point reached determines the fire-endurance period. The hose-stream test is applied to all bearing and nonbearing walls achieving a fire endurance of one hour or greater.

Model Code Requirements for Fire Resistance

Although not explicitly stated, there are four reasons why building codes specify fire-resistance ratings for building members and assemblies. These are

1. To provide for the safe egress of building occupants.
2. To provide time for the fire service to mount an interior fire attack.
3. To limit fire spread through and maintain the structural integrity of the building of fire origin.
4. To provide protection for exposed properties adjacent to the building of fire origin.

When the member or assembly being considered is an exterior wall, the required rating is dependent on whether the wall is a bearing wall or a nonbearing wall and on separation distance from adjacent property lines.

As stated earlier, the rationale for distinguishing between structural and barrier fire resistance is already present in the model codes. Although not stated explicitly, it can be deduced by analysis of current model-code provisions. This can best be illustrated by the following example.

Consider the hypothetical building shown in Fig. 2. Assume that this is a single-story factory building (see Fig. 2 for occupancy classification) constructed of the most fire-resistive construction recognized by each model code. The required fire-resistance ratings for each wall would be as shown in Table 1.

The numbers and abbreviations shown in parentheses in Table 1 represent limitations on the area of protected and unprotected openings allowed in the wall. Limitations on protected and unprotected openings indicate that an assembly must perform a fire-barrier function.

For illustrative purposes, the specific provisions contained in the Standard Building Code will be examined. The conclusions drawn from the example apply to the BOCA Basic/National Building Code and the Uniform Building Code.

Focus for a moment on wall A-B, a non-load-bearing exterior wall located 40 ft from the lot line. The required fire-resistance rating of this wall is zero. No structural fire-resistance rating is required since the wall is non-load-bearing. No barrier fire-

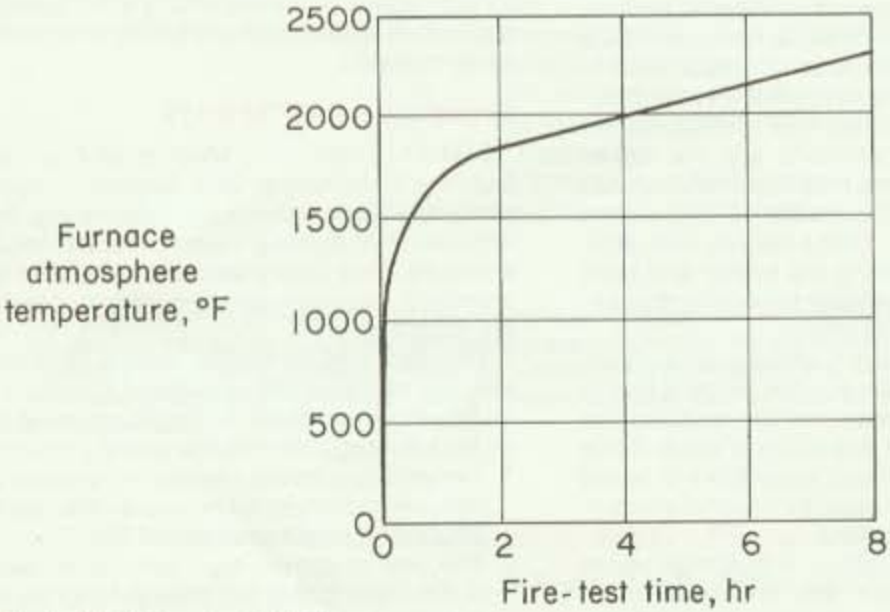
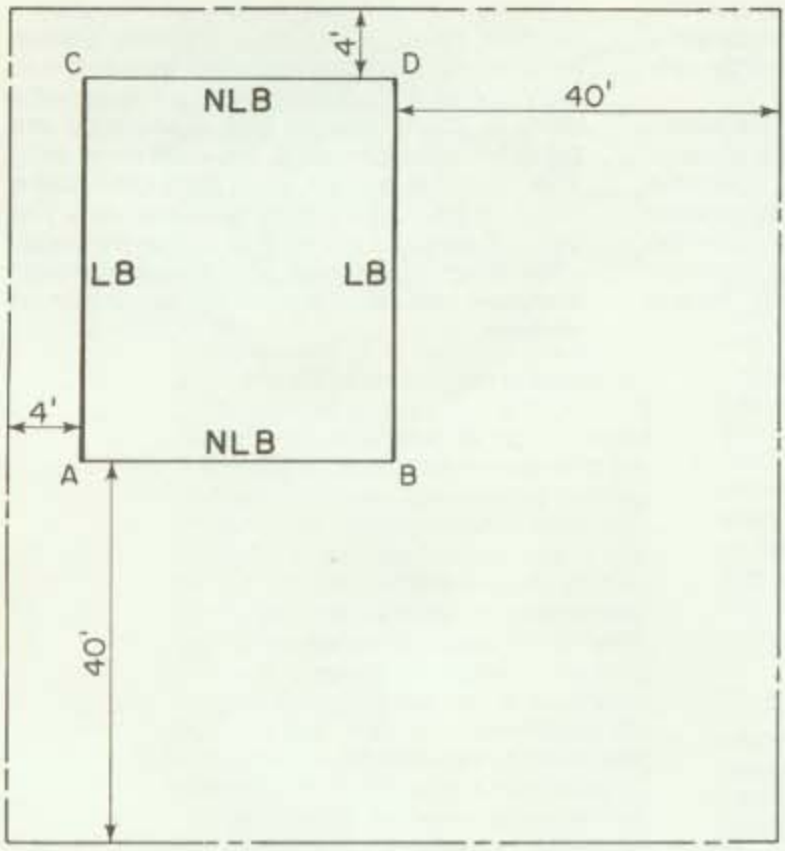


Fig. 1. ASTM Standard E119 time-temperature curve.



Occupancy classification

BOCA: Use group F-2
SBC: Factory-industrial occupancy—group F
UBC: Use group B-2

Fig. 2.

Table 1. Required Fire-Resistance Rating for Exterior Walls

		Fire-resistance rating, hr			
		Wall			
Model code	Construction type	A-B Non-load-bearing 40-ft separation	B-D Load-bearing 40-ft separation	C-D Non-load-bearing 4-ft separation	A-C Load-bearing 4-ft separation
BOCA[1]	1A	0 (NL) Unexposed surface temperature criteria waived (per section 1406.2.4)	4 (NL) Unexposed surface temperature criteria waived (per section 1406.2.4)	1 (15% P, UP openings not permitted)[4]	4 (15% P, UP openings not permitted)[4]
SBC[2]	I	0 (NL) NC	4 (NL) NC	2 (10% P)	4 (10% P)
UBC[3]	I-FR	0 (NL UP)	2 (50% UP)	2 (0%)	4 (0%)

P = Maximum area of protected openings
UP = Maximum area of unprotected openings
NL = No limit on openings
NC = Noncombustible
1 Derived using provisions of Table 401 and Section 1406 from BOCA 1984 with 1986 Accumulative Supplement
2 Derived using the provisions of Table 600 from SBC-1985.
3 Derived using provisions of Tables 5-A and 17-A, Sections 1803 and 504 of the Uniform Building Code 1985.
4 Unexposed surface temperature rise requirements of ASTM E 119 do not apply provided correction is made for radiation from the unexposed exterior wall surface per section 1406.2.4.

resistance rating is required since the wall is located at a code-assumed "safe distance" from the lot line. Also note that there is no limit on unprotected openings, further indication that no fire-barrier function is required.

Compare this with load-bearing wall B-D, which is required to provide a four-hour fire-resistance rating. Like wall A-B, wall B-D is located 40 ft from the adjacent lot line. However, unlike wall A-B, wall B-D is a load-bearing wall. Since 40-ft horizontal separation exists and no limit is placed on openings, it can be concluded that wall B-D, like wall A-B, needs no barrier fire-resistance rating. It can be deduced that the four-hour requirement for wall B-D is a structural fire-resistance requirement.

Next, consider wall C-D, which is an exterior nonbearing wall located only 4 ft from the adjacent lot line and required to have a two-hour fire-resistance rating. Since wall C-D is nonbearing, it is apparent that the two-hour rating is a barrier fire-resistance rating related to the close proximity of wall C-D to the lot line. This is reinforced by the fact that all openings are required to be protected and are limited to a total of 10% of the wall area.

Finally, consider wall A-C, which is a load-bearing wall located only four feet from the adjacent lot line. The required barrier fire-resistance rating and limits on openings for wall A-C would be the same as wall C-D since they are both within 4 ft (see SBC-1985, Table 600) from their adjacent lot lines. However the required fire-resistance rating for wall A-C is not two hours as for wall C-D but four hours, the same as for load-bearing wall B-D. It is obvious that the four-hour rating requirement for wall A-C is a structural fire-resistance requirement, not a barrier fire-resistance requirement.

This example demonstrates that the rationale for distinguishing between structural fire resistance and barrier fire resistance already exists in the model codes.

Benefits of Separating Structural and Barrier Fire-Resistance End Points

Distinguishing between structural and barrier fire-resistance ratings in ASTM E119 and the model codes would eliminate material waste and increase construction economy. The following examples illustrate some specific cases where significant benefits would be realized.

Precast Concrete Wall Panels

Load-bearing precast, prestressed double-tee wall panels are utilized extensively for industrial and commercial construction. Double tees can be constructed with flanges as thin as 1.5 in. and still maintain a two-hour structural fire-resistance rating. However, in order to achieve a two-hour fire-resistance rating under current provisions of ASTM E119 and the model codes, a minimum flange thickness of 4.6 in. for normal weight concrete or 3.6 in. for structural lightweight concrete is required. If a two-hour fire-resistance rating is required for structural reasons only, a savings of 3.1 in. of concrete (4.6 in. - 1.5 in.) would be realized if the double tee had separate ratings for structural fire resistance and barrier fire resistance. Considering that the value of a cubic yard of normal-weight concrete cast in the precast plant is approximately $75, the increased cost of constructing the panel with a 4.6-in. flange is about $0.70 per sq ft of wall. For a 200x400-ft building with 30-ft high walls this would result in a material cost savings of $26,000.

Furthermore, the additional concrete increases the weight of the double-tee panel by over 35 lb per sq ft which results in increased foundation costs and increased costs for transportation and handling at the jobsite.

Tilt-up Wall Panels

Tilt-up wall panels are also used for industrial and commercial construction in many parts of the country. A panel thickness of 5.5 in. is frequently used. The structural fire resistance of a 5.5-in. tilt-up panel of normal-weight concrete typically exceeds four hours, while its barrier fire-resistance end point occurs between two and three hours. Currently, if a four-hour rating is required, the thickness of the tilt-up panel would have to be increased to as much as seven inches to satisfy the barrier fire-resistance criteria of ASTM E119. If the four-hour rating is required only for structural considerations, the additional panel thickness is unnecessary since a 5.5-in. tilt-up panel already has a four-hour structural fire-resistance rating.

The potential benefits from determining both a barrier fire-resistance rating and a structural fire-resistance rating are obvious.

Recommendations

In view of the material savings and economic benefits that would become possible by differentiating between the structural fire resistance and barrier fire resistance of building members and assemblies, it is recommended that ASTM E119 "Standard Methods of Fire Tests of Building Construction and Materials" and the three model codes be revised to make this distinction.

Modification of ASTM E119

Provisions for determining structural fire resistance and barrier fire resistance are already contained in ASTM E119. The only revision needed is to include wording allowing the determination of a rating for each rather than establishing a single rating based on the first end point reached. This can be accomplished by revising the following articles of ASTM E119 as indicated.

2.3.1.4 For load-bearing elements, establishment of separate fire-endurance classifications based on conditions outlined in 2.3.1.1, 2.3.1.2, and 2.3.1.3.

8.2 For the purpose of obtaining additional performance data in tests of load-bearing walls, floors, and roofs, when the fire endurance classification is established by conditions described in Sections 2.3.1.1 and 2.3.1.2, the test may be continued, provided no structural failure has occurred or no hazardous condition exists, until a separate structural fire-endurance classification is established.

Commentary to 8.2

Establishment of a separate fire-endurance classification for each of the conditions outlined in 2.3.1.1, 2.3.1.2, 2.3.1.3 allows fire endurance to be classified according to the function required of the element under consideration by building codes. Load-bearing exterior walls with adequate separation from lot lines, or with allowances for unprotected openings, may not be required by codes to perform barrier fire-resistance functions. These members are required to maintain structural integrity during fire but, due to separation distance and other code provisions, are not required to limit fire spread due to heat transmission or passage of hot gases.

Load-bearing elements receiving their fire-endurance classification based on conditions described in 2.3.1.1 and 2.3.1.2, but whose function is to provide structural fire resistance, may be classified according to their fire-resistive function within the building.

9.6 Exception: When separate barrier and structural fire-endurance classifications are established, as described in section 8.2, the hose-stream test shall be conducted after subjecting a specimen to a fire-exposure test for a period equal to one-half the desired barrier *or* structural fire-endurance rating period but not to exceed one hour.

Revision of Model Building Codes

The only revisions required in the model codes would be to specify both a structural fire-resistance rating and a barrier fire-resistance rating for building elements where presently only one rating is specified. This would be accomplished by revising Table 401 of the BOCA Building Code, Table 600 of the Standard Building Code, and Table 17-A of the Uniform Building Code. Instead of indicating a single fire-resistance rating requirement, a dual designation would be shown. For example, the fire-resistance rating for exterior bearing walls in Type I construction (SBC) over 30 ft from the adjacent property line would be designated 4/0 (i.e., four-hour structural fire-resistance rating, 0 hours fire-barrier resistance rating). If this were done, the fire-resistance ratings shown in Table 1 for the example building shown previously would be revised as shown in Table 2. Limits to protected and unprotected openings would be applied where barrier, or structural and barrier, fire resistance is required.

Conclusions

Allowing both structural fire-resistance ratings and barrier fire-resistance ratings to be determined for load-bearing walls will make possible significant savings in materials, labor, and construction time. The rationale for making this distinction is already present in the model codes, although not explicitly stated.

In order to take advantage of the potential savings, two changes should take place. First, ASTM E119 should be revised to allow specific determination of both a structural fire-resistance rating and a barrier fire-resistance rating. Criteria for determining both types of ratings are already specified. However, only one rating is currently recognized based on the first end point reached.

Second, required fire-resistance ratings specified in the model codes should be modified to indicate both a structural fire-resistance rating and a barrier fire-resistance rating. This can be accom-

Table 2. Revised Fire-Resistance Ratings: Structural/Barrier

		Fire-resistance rating, hr			
Model code	Construction type	NLB wall A-B	LB wall B-D	NLB wall C-D	LB wall A-C
BOCA	1A	0/0	4/0	0/1	4/1
SBC	I	0/0	4/0	0/2	4/2
UBC	I-FR	0/0	2/0	0/2	4/2

NLB = Non-load-bearing
LB = Load-bearing

plished by adopting a rating format such as 4/2 to specify a four-hour structural fire resistance and a two-hour fire-barrier resistance. Currently only one rating requirement is indicated.

On a final note, there may be concern that adopting a rating system that distinguishes between structural and barrier fire resistance is unfeasible because it would nullify the results of all previous tests conducted under ASTM E119. This is not the case. Previously rated assemblies would merely be assigned a dual rating determined by the end point which governed its test.

For example, if a load-bearing wall received a two-hour rating based on unexposed surface temperature rise or passage of hot gases, its performance as a fire barrier would be assigned a rating of 2/2 to indicate both a structural and barrier fire-resistance rating. This would be conservative since the fire test would have confirmed a structural fire resistance of at least two hours. The option to establish a greater structural fire-resistance rating through retesting or through approved analytical calculation procedures would then be available.

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