Fire Protection Engineer - What is it?

Fire protection engineering is the application of science and engineering principles to protect people and their environment from destructive fire, which includes:

- analysis of fire hazards
- mitigation of fire damage by proper design, construction, arrangement, and use of buildings
- materials, structures, industrial processes, and transportation systems
- the design, installation and maintenance of fire detection and suppression and communication systems, and
- post/fire investigation and analysis.
Role of an FPE

- Fire protection engineers design systems that, taken individually, could be considered mechanical (fire sprinklers, fire-fighter's standpipes, smoke control), electrical (fire alarm), architectural (means of egress design), or structural (fire resistance design).

← Sample Life Safety Plan (partial)
Role of an FPE

- Fire protection engineers design systems that, taken individually, could be considered mechanical (fire sprinklers, fire-fighter's standpipes, smoke control), electrical (fire alarm), architectural (means of egress design), or structural (fire resistance design).

← Interface with other disciplines and hi-ex foam system
Role of an FPE

• For most projects, fire protection engineering is largely practiced through the application of prescriptive codes and standards. Broad classifications of occupancies, prescriptive codes, and standards identify requirements.
Role of an FPE

• Prescriptive Advantages:
  – Prescriptive codes and standards are easy to apply and enforce.
  – Buildings designed to prescriptive codes and standards have a good history of performance in fires.

• Prescriptive Disadvantages:
  – Does not result in uniform levels of safety or cost-benefit. For example, stores classified as mercantile occupancies. A store that sells greeting cards would fall under this occupancy classification, as would a store that sold liquor in bottles. Although the protection that would be required in these stores would be similar, the fire hazard presented by these stores would be different.
Role of an FPE

- In some cases non-prescriptive options are beneficial
  - "Performance-based design",
  - Variances, or
  - Alternative Means and Methods

104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.
FPE for Structural Engineers

- Topics
  - Determination of Construction Type (How-to)
  - Required Rating of Building Elements
    - Structural Frame, Floor construction, Bearing Walls, Roofs
  - UL Assemblies
    - Restrained vs. Unrestrained
    - Member substitution
    - SFRM Thickness Adjustment
    - Restrained Beam-only substitutions
    - Example(s)
  - Non prescriptive approaches
  - Fire Walls and Party Walls
    - Requirements
    - Types
### Construction Type

**Table 503**

![Table 503](image-url)
Construction Type

- Required minimum Construction Type is based on Occupancy and planned building height / area

- In general the larger the building of a given Occupancy the more fire-resistant construction is required

---

**Table 503**

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Most fire-resistant)</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>HT</td>
</tr>
<tr>
<td>(Least fire-resistant)</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>

**Diagram**

- Designer will usually enter from the occupancy-group side of Table 503.
- Intended occupancy and desired building height and area will determine the type of construction allowable under the Code. For example, a minimum of Type III-B construction would be required for a Group I-1 occupancy housed in a 3-story building with 10,000 sf (929 m²) in area per floor.
### Construction Type

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td>(See Table 601)</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>Heavy</td>
<td>B</td>
</tr>
<tr>
<td>A</td>
<td>Fire-Rated</td>
<td>Fire-Rated</td>
<td>Partially rated</td>
<td>Timber</td>
<td>Non-rated</td>
</tr>
</tbody>
</table>

#### Occupancy

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2</td>
<td>65/3/15,500 sf</td>
<td>55/2/9,500 sf</td>
<td>65/3/15,000 sf</td>
<td>40/1/6,000 sf</td>
<td></td>
</tr>
<tr>
<td>(Restaurant)</td>
<td>19.9 m/3/1140 m²</td>
<td>18.8 m/2/1983 m²</td>
<td>19.8 m/3/1394 m²</td>
<td>12.2 m/1/557 m²</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>65/5/37,500 sf</td>
<td>55/4/19,000 sf</td>
<td>65/5/36,000 sf</td>
<td>40/2/9,000 sf</td>
<td></td>
</tr>
<tr>
<td>(Business)</td>
<td>19.9 m/5/3494 m²</td>
<td>16.0 m/4/1795 m²</td>
<td>19.0 m/5/3344 m²</td>
<td>12.2 m/5/636 m²</td>
<td></td>
</tr>
</tbody>
</table>

EwingCole
Construction Type

- Construction type prescribes minimum required protection of building attributes and may prohibit use of combustible elements

<table>
<thead>
<tr>
<th>Materials</th>
<th>Protected Elements</th>
<th>Less Protected Elements</th>
<th>Unprotected Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncombustible</td>
<td>Type I-A, II-A</td>
<td>Type I-B</td>
<td>Type II-B</td>
</tr>
<tr>
<td>Combustible</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Mixed Systems</td>
<td>Type III-A</td>
<td>Type III-B</td>
<td>—</td>
</tr>
<tr>
<td>Heavy Timber</td>
<td>—</td>
<td>Type IV</td>
<td>—</td>
</tr>
<tr>
<td>Any Materials</td>
<td>Type V-A</td>
<td>—</td>
<td>Type V-B</td>
</tr>
</tbody>
</table>

*Note that levels of fire resistance decrease from left to right and top to bottom of this table.*

EwingCole
## Required rating of elements

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A°</td>
<td>B</td>
<td>HT</td>
</tr>
<tr>
<td>Structural frame®</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>HT</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1/HHT</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>See Table 602</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interior</td>
<td>See Section 602.4.6</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor construction</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>HT</td>
</tr>
<tr>
<td>Including supporting beams and joists</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof construction</td>
<td>1 1/2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;,&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;,&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;,&lt;sup&gt;d&lt;/sup&gt;</td>
<td>HT</td>
</tr>
<tr>
<td>Including supporting beams and joists</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;,&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;,&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td>1&lt;sup&gt;c&lt;/sup&gt;,&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

For SI: 1 foot = 304.8 mm.

a. The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.

b. Roof supports: Fire-resistance ratings of structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

c. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
### Required ratings – Caution!

#### TABLE 601
**FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)**

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A&lt;sup&gt;a&lt;/sup&gt;</td>
<td>B</td>
<td>HT</td>
</tr>
<tr>
<td>Structural frame&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>HT</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior&lt;sup&gt;g&lt;/sup&gt;</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1/HT</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>See Table 602</td>
</tr>
<tr>
<td>Nonbearing walls and partitions&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>See Section 602.4.6</td>
</tr>
<tr>
<td>Floor construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Including supporting beams and joists</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>HT</td>
</tr>
<tr>
<td>Roof construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Including supporting beams and joists</td>
<td>1&lt;sub&gt;1/2&lt;/sub&gt;&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>1&lt;sub&gt;e,d&lt;/sub&gt;</td>
<td>0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>HT</td>
</tr>
</tbody>
</table>

For SI: 1 foot = 304.8 mm.

- a. The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.
- b. Roof supports: Fire-resistance ratings of structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.
- c. Except in high-rise buildings, Group A, E, F-1, H, I, L, M, R-1, R-2 and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. For high-rise buildings, Group A, E, I, L, R-1 and R-2 occupancies and other applications listed in Section 111 regulated by the Office of the State Fire Marshal, fire protection of members other than the structural frame shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
Required rating of elements

• Question: which steel is frame, which is floor construction, and which is neither?

• The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads.

• The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.
Required rating of elements

- Footnote a: The definitions of what constitutes the structural frame are contained in this footnote to the table. Only those primary elements framing directly into the columns need meet the protection criteria noted.
- We interpret this footnote to mean that lateral bracing, which is not a primary element, need not be fire protected.
- The other elements not making up the structural frame are covered by the requirements for floor and roof construction.

EwingCole
The UL Directory is an approved design source based upon the ASTM E119 standard.

UL Websites:


### UL Assemblies


---

#### U.L. Fire Ratings - Composite Deck, cont’d.

<table>
<thead>
<tr>
<th>U.L. Des. No.</th>
<th>F.R.</th>
<th>Concrete/Cover</th>
<th>USD Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>D216</td>
<td>S</td>
<td>2 ½ NW, LW</td>
<td>BL, BL, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D502</td>
<td>S</td>
<td>2 ½ NW</td>
<td>BL, BL, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D703</td>
<td>C</td>
<td>2 ½ NW, LW</td>
<td>BL, BL, LF15, LF1C, LF2, LF2C, LF3, LF3C, NL, NLC*</td>
</tr>
<tr>
<td>D704</td>
<td>C</td>
<td>2 ½ NW</td>
<td>BL, BL, LF15, LF1C</td>
</tr>
<tr>
<td>D708</td>
<td>C</td>
<td>2 ½ NW</td>
<td>LF3, LF3C</td>
</tr>
<tr>
<td>D923</td>
<td>N</td>
<td>3 ½ LW</td>
<td>BL, BL, LF15, LF1C, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D925</td>
<td>N</td>
<td>4 ½ NW</td>
<td>BL, BL, LF15, LF1C, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D925</td>
<td>N</td>
<td>3 ½ LW</td>
<td>BL, BL, LF15, LF1C, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D927</td>
<td>N</td>
<td>4 ½ NW</td>
<td>BL, BL, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D927</td>
<td>N</td>
<td>3 ½ lw</td>
<td>BL, BL, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D929</td>
<td>N</td>
<td>4 ½ NW</td>
<td>BL, BL, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
<tr>
<td>D929</td>
<td>N</td>
<td>3 ½ LW</td>
<td>BL, BL, LF2, LF2C, LF3, LF3C, NL, NLC</td>
</tr>
</tbody>
</table>

---

**FIRE RATINGS, CONT'D**

48
UL Assemblies

- Question: Is my construction restrained or unrestrained

- IBC (703.2.3) states assemblies “shall not be considered to be restrained unless evidence satisfactory to the building official is furnished by the registered design professional showing that the construction qualifies for a restrained classification in accordance with ASTM E 119. Restrained construction shall be identified on the plans.”
UL Assemblies

- The UL Directory defines restraint conditions as those meeting Appendix C of UL Standard 263. This listing as well as Table X3.1 of the ASTM E119 Appendix X3 qualifies most common types of steel framed construction (except some wall-bearing joist systems, which may not have resistance to thermal expansion) as restrained.
### TABLE X3.1 Construction Classification, Restrained and Unrestrained

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Restrained/Unrestrained</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Wall bearing:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single span and simply supported end spans of multiple bays:&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Open-web steel joists or steel beams, supporting concrete slab, precast units, or metal decking</td>
<td>unrestrained</td>
<td></td>
</tr>
<tr>
<td>2. Concrete slabs, precast units, or metal decking</td>
<td>unrestrained</td>
<td></td>
</tr>
<tr>
<td>Interior spans of multiple bays:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Open-web steel joists, steel beams or metal decking, supporting continuous concrete slab</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td>2. Open-web steel joists or steel beams, supporting precast units or metal decking</td>
<td>unrestrained</td>
<td></td>
</tr>
<tr>
<td>3. Cast-in-place concrete slab systems</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td>4. Precast concrete where the potential thermal expansion is resisted by adjacent construction&lt;sup&gt;b&lt;/sup&gt;</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td><strong>II. Steel framing:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Steel beams welded, riveted, or bolted to the framing members</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td>2. All types of cast-in-place floor and roof systems (such as beam-and-slabs, flat slabs, pan joists, and waffle slabs) where the floor or roof system is secured to the framing members</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td>3. All types of prefabricated floor or roof systems where the structural members are secured to the framing members and the potential thermal expansion of the floor or roof system is resisted by the framing system or the adjoining floor or roof construction&lt;sup&gt;b&lt;/sup&gt;</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td><strong>III. Concrete framing:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Beams securely fastened to the framing members</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td>2. All types of cast-in-place floor or roof systems (such as beam-and-slabs, flat slabs, pan joists, and waffle slabs) where the floor system is cast with the framing members</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td>3. Interior and exterior spans of precast systems with cast-in-place joints resulting in restraint equivalent to that which would exist in condition III (1)</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td>4. All types of prefabricated floor or roof systems where the structural members are secured to such systems and the potential thermal expansion of the floor or roof systems is resisted by the framing system or the adjoining floor or roof construction&lt;sup&gt;b&lt;/sup&gt;</td>
<td>restrained</td>
<td></td>
</tr>
<tr>
<td><strong>IV. Wood construction:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All types</td>
<td>unrestrained</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Floor and roof systems can be considered restrained when they are tied into walls with or without tie beams, the walls being designed and detailed to resist thermal thrust from the floor or roof system.

<sup>b</sup> For example, resistance to potential thermal expansion is considered to be achieved when:

1. Continuous structural concrete topping is used,
2. The space between the ends of precast units or between the ends of units and the vertical face of supports is filled with concrete or mortar, or
3. The space between the ends of precast units and the vertical faces of supports, or between the ends of solid or hollow core slab units does not exceed 0.25 % of the length for normal weight concrete members or 0.1 % of the length for structural lightweight concrete members.
# Assembly attributes

<table>
<thead>
<tr>
<th>SPRAY ON</th>
<th>CONCRETE</th>
<th>DECKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NW</td>
<td>LW</td>
</tr>
<tr>
<td>Applied on Deck</td>
<td>Wet Surry</td>
<td>Nozzle applied Fiber</td>
</tr>
<tr>
<td></td>
<td>147-153 psf</td>
<td>107-113 pcf</td>
</tr>
<tr>
<td></td>
<td>114-120 pcf</td>
<td>9/16&quot; Form Deck</td>
</tr>
<tr>
<td></td>
<td>1 5/16&quot; Form Deck</td>
<td>1 1/2&quot; Comp Deck</td>
</tr>
<tr>
<td></td>
<td>1 5/8&quot; Comp Deck</td>
<td>2&quot; Comp Deck</td>
</tr>
<tr>
<td></td>
<td>3&quot; Comp Deck</td>
<td>4 1/2&quot; Comp Deck</td>
</tr>
<tr>
<td></td>
<td>Fluted Deck</td>
<td>Cellular Deck</td>
</tr>
<tr>
<td></td>
<td>Steel joist option</td>
<td>Roof applications</td>
</tr>
<tr>
<td></td>
<td>4 hr Rating Available</td>
<td>Composite Beams</td>
</tr>
<tr>
<td>D-739</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-743</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-744</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-759</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-779</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-780</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-782</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-832</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-858</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-859</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-860</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-902</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D-925</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tested beam sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>W8x28 W6x12</td>
</tr>
<tr>
<td>W8x20 W8x28</td>
</tr>
<tr>
<td>W6x15.5</td>
</tr>
<tr>
<td>W8x28</td>
</tr>
<tr>
<td>W8x28 W12x16</td>
</tr>
<tr>
<td>W8x28</td>
</tr>
<tr>
<td>W8x28</td>
</tr>
<tr>
<td>W8x24 W8x28</td>
</tr>
<tr>
<td>W10x25</td>
</tr>
<tr>
<td>W8x20</td>
</tr>
<tr>
<td>W8x20 W8x28</td>
</tr>
<tr>
<td>W8x28 W12x14</td>
</tr>
<tr>
<td>W8x28 W12x16</td>
</tr>
</tbody>
</table>
Adjustments and Substitutions

• In tests where SFRM is used, the UL Directory lists the size of the tested element as a minimum beam size (ie. minimum $W/D$ ratio). Many of these members are shallow, heavy $W$-sections that are rarely found in an economical structural design. Therefore, a procedure is necessary to convert SFRM thickness requirements from these tests to suit the member actually used in the design. SFRM thickness adjustments for both complete roof and floor assembly tests and beam-only tests can be made in one of two ways:
  1. Larger $W/D$ Substitution
  2. SFRM Thickness Adjustment Equation
Larger W/D Substitution

By listing a minimum beam size, each assembly essentially prescribes a minimum W/D ratio to be met. Any beam section with a larger W/D value than that listed may be directly substituted into the assembly without changing the SFRM thickness.

However, because the listings often specify shallow, compact members with relatively high W/D ratios, this method may not be suitable for many economical beam sections. In these cases the thickness adjustment equation must be used. Even in instances when an element does have a larger W/D ratio than that listed and may be directly substituted, it is advisable to check the thickness adjustment equation as a smaller amount of fireproofing may be permitted.
SFRM thickness Adjustment Formula

- Results of UL fire tests of beams with varying SFRM thickness show a strong relationship between the time until a limiting temperature or beam failure is reached to the thickness of SFRM applied and the member's $W/D$ ratio. The following relationship provides a logical approach for varying the thickness of SFRM applied to a substituted beam based on its W/D ratio.

The UL Directory allows the formula to be utilized in both restrained and unrestrained cases as long as the restrained beam is classified as compact.

\[ T_1 = \frac{\left( \frac{W}{D} + 0.6 \right) \cdot T_2}{\left( \frac{W}{D_1} + 0.6 \right)} \]

(VII-1)

where:
- $T_1$ = Thickness (in.) of spray applied material
- $W$ = Weight of beam (lb / ft)
- $D$ = Perimeter of protection, at the interface of the protection material and the steel through which heat is transferred to steel (in.)

Subscript 1 = Refers to desired beam size and required material thickness.
Subscript 2 = Refers to given beam size and material thickness shown on the individual design.
The beam substitution equation is subject to the following qualifications:

1. *W/D values for the beam must not be less than 0.37.*
2. $T_1$ values must not be less than 3/8 in. (9.5 mm).
3. The Unrestrained Beam Rating is not less than 1 hour.
4. The Restrained Beam Rating is not less than 1 hour.
5. When used to determine the thickness to be applied to a restrained beam, the desired beam must be classified as compact as per Part B5.1 and Table B5.1 of the AISC LRFD Specification for Structural Steel Buildings 7. For A992 steel W shapes, relatively few sections (W21x48, W14x99, W14x90, W12x65, W10x12, W8x31, W8x10, W6x15 and W6x8.5) are classified as noncompact.
SFRM Adjustment

• This adjustment has also been added prescriptively to the IBC in order to remove confusion.
Standardized beam-only tests provide fire test results of beams with various fire protection methods without the necessity of reconstructing the entire floor assembly each time a test is run. However, because only representative sections of roof or floor constructions are used in the beam-only test, they must be incorporated into compatible complete assembly tests before they may be used to meet the requirements of building code fire ratings. The UL Directory lists beam-only tests in the N and S design series.
One more substitution – Beam Only

- Beam-only tests are commonly used in instances where the authority having jurisdiction requires a higher rating for beams acting as the structural frame (i.e. IBC Type IA) than for the rest of the floor or ceiling assembly. In these cases, fire protection for the structural frame may be accomplished by substituting an N or S series beam only design meeting the frame rating requirements into a complete roof or floor assembly test of a lesser rating. Other instances where a beam-only test can be used are when the complete assembly test does not specify a steel beam, or when the profile or type of beam desired is different than that listed in the assembly.
UL provides specific requirements as to when this substitution may take place. These requirements are:

1. Non-composite or composite beams may be substituted into assemblies with composite beams. Only non-composite beams may be incorporated into assemblies with non-composite tests.

2. Beam-only designs may only be used in complete roof or floor assembly tests that have a "similar or greater capacity for heat dissipation from the beam" than the beam-only test. For concrete floors, greater density range and volume per unit floor area provide a greater heat dissipation capacity.

3. Beam-only designs shall have an equal or greater unrestrained beam rating than the complete roof or floor assembly unrestrained beam rating.

4. Beam-only designs requiring roof or floor deck fire protection (N400-N800 design series) may be incorporated into assemblies with unprotected decks as long as the beam fire protection material is oversprayed for 12 in. on either side of the beam. The thickness of the oversprayed material shall be the same as required for the beam. Beam-only designs with unprotected decks (N900 design series) may be incorporated directly into complete assembly tests with unprotected decks with no overspraying required.
UL Assemblies – Example 1

- Determine the thickness of SFRM required to meet the Construction Type IA requirements for the floor section shown. An unprotected deck design is to be used.
• Construction Type IA, requires a 2-hour rating for the floor construction, but requires a 3-hour rating for the structural frame. The IBC designates components "having direct connections to the columns" as members of the structural frame. Therefore the W18x55 girders, as well as the W14x22 members along column lines 1 and 2 require a 3-hour rating.
UL Assemblies – Example 1

- All steel structures are classified as restrained; therefore a UL beam-only design supporting a 3-hour restrained beam-only rating must be found and incorporated into a 2-hour floor assembly.

- The selected assembly must support the use of composite beams, lightweight concrete and fluted deck. The selected beam-only design must support the use of composite beams. In this example, the unprotected deck assembly UL D925 and beam-only design UL N782 will be evaluated.
UL Assemblies – Example 1

- See below a summary of the SFRM thickness amounts required by UL D925 for a W8x28 beam coated with W. R. Grace Type MK-6 material.
UL Assemblies – Example 1

• Question: Which row to choose?
• UL D925 lists several unrestrained beam ratings for each restrained assembly rating.

• The beam rating for a Restrained assembly is not equal to the assembly rating itself. For example, in a 2 hour Restrained assembly, the beam is rated for just 1 hour. This is because the criteria for a Restrained assembly, is not the temperature at which the beam fails, but whether or not the assembly as a whole can support the design load for 2 hours; also the temperature on the unexposed surface can not exceed 250°F above ambient or ignite cotton waste placed on the top surface of the assembly.
• Question: Which row to choose?
• UL D925 lists several unrestrained beam ratings for each restrained assembly rating.

<table>
<thead>
<tr>
<th>Restrained Assembly Rating Hr</th>
<th>Unrestrained Assembly Rating Hr</th>
<th>Unrestrained Beam Rating Hr</th>
<th>W8x28 Beam</th>
<th>W8x28 Beam Supporting All Fluted Floor Units w/Lightweight Concrete</th>
<th>W12x16 Beam</th>
<th>W12x16 Beam Supporting All Fluted Floor Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9/16</td>
<td>7/16+</td>
<td>3/4</td>
<td>5/8</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1</td>
<td>1</td>
<td>9/16</td>
<td>7/16+</td>
<td>3/4</td>
<td>5/8</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1-1/2</td>
<td>1-1/2</td>
<td>7/8</td>
<td>3/4</td>
<td>1-3/16</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>9/16</td>
<td>7/16+</td>
<td>3/4</td>
<td>5/8</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1-3/16</td>
<td>1</td>
<td>1-5/8</td>
<td>1-3/8</td>
</tr>
<tr>
<td>3</td>
<td>1-1/2</td>
<td>1-1/2</td>
<td>7/8</td>
<td>3/4</td>
<td>1-3/16</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1-3/4</td>
<td>1-9/16</td>
<td>2-3/8</td>
<td>2-1/8</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2-5/16</td>
<td>2-1/16</td>
<td>3-1/8</td>
<td>2-3/4</td>
</tr>
</tbody>
</table>
UL Assemblies – Example 1

- Question: Which row to choose?
- UL D925 lists several unrestrained beam ratings for each restrained assembly rating.

<table>
<thead>
<tr>
<th>Restrained Assembly Rating Hr</th>
<th>Unrestrained Assembly Rating Hr</th>
<th>Unrestrained Beam Rating Hr</th>
<th>W8x28 Beam</th>
<th>W8x28 Beam Supporting All Fluted Floor Units w/Lightweight Concrete</th>
<th>W12x16 Beam</th>
<th>W12x16 Beam Supporting All Fluted Floor Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9/16</td>
<td>7/16+</td>
<td>3/4</td>
<td>5/8</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1</td>
<td>1</td>
<td>9/16</td>
<td>7/16+</td>
<td>3/4</td>
<td>5/8</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1-1/2</td>
<td>1-1/2</td>
<td>7/8</td>
<td>3/4</td>
<td>1-3/16</td>
<td>1</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
<td><strong>9/16</strong></td>
<td><strong>7/16+</strong></td>
<td><strong>3/4</strong></td>
<td><strong>5/8</strong></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1-3/16</td>
<td>1</td>
<td>1-5/8</td>
<td>1-3/8</td>
</tr>
<tr>
<td>3</td>
<td>1-1/2</td>
<td>1-1/2</td>
<td>7/8</td>
<td>3/4</td>
<td>1-3/16</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1-3/4</td>
<td>1-9/16</td>
<td>2-3/8</td>
<td>2-1/8</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2-5/16</td>
<td>2-1/16</td>
<td>3-1/8</td>
<td>2-3/4</td>
</tr>
</tbody>
</table>
UL Assemblies – Example 1

- A 2-hour restrained assembly rating with a 1-hour unrestrained beam rating is an acceptable solution for this example and requires the least amount of fireproofing material.
- Therefore, a 7/16-in thickness applied to the W8x28 test beam supporting all fluted floor units with lightweight concrete will be chosen.
UL Assemblies – Example 1

• In order to use the SFRM adjustment formula, the beam members must be compact. Both the W14x22 and W18x55 are classified as compact sections.

\[ \text{W14x22, } W/D = 0.53 \]

• The W14x22 floor member has a \( W/D \) less than that of the tested W8x28 beam \( (W/D = 0.82) \), therefore the SFRM thickness adjustment equation must be used.

\[ T_1 = \left( \frac{0.82 + 0.6}{0.53 + 0.6} \right) \times 0.4375 = 0.55 \]

use 9/16-in
UL Assemblies – Example 1

- Protection for the structural frame members will now be determined using UL N782

- First check to ensure it has a concrete slab with lower capacity for dissipating heat away from the beam than the floor assembly.
UL Assemblies – Example 1

- Slab Design: UL N782 supports the use of both normal weight and lightweight concrete. For lightweight concrete, it specifies a unit weight of 110 pcf. When no unit weight range is given, the commentary in the UL Directory allows a tolerance of plus or minus 3 pcf. Therefore, the concrete unit weight of 107·113 pcf is within the range of UL D925. The 2 ½ in. concrete thickness for UL N782 is less than the thickness specified in UL D925; therefore it meets the requirement of having a lower heat dissipation capacity than the floor system.
UL Assemblies – Example 1

- SFRM thickness amounts required by UL N782 for a W8x28 beam coated with W. R. Grace Type MK-6 material is shown. A 3-hour restrained fire-rating is required.

<table>
<thead>
<tr>
<th>Rating Hr</th>
<th>Restrained Beam</th>
<th>Unrestrained Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5/16</td>
<td>5/16</td>
</tr>
<tr>
<td>1-1/2</td>
<td>7/16</td>
<td>11/16</td>
</tr>
<tr>
<td>2</td>
<td>11/16</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1-3/16</td>
<td>1-5/16</td>
</tr>
<tr>
<td>4</td>
<td>1-5/8</td>
<td>1-5/8</td>
</tr>
</tbody>
</table>
Therefore, a 1 3/16 in. thickness applied to the W8x28 test beam (W/D = 0.82) supporting all fluted floor units with lightweight concrete will be chosen. W14x22. W/D = 0.53

\[ T_1 = \left( \frac{0.82 + 0.6}{0.53 + 0.6} \right) \times 1.19 = 1.49 \]

Use 1 1/2 in.

<table>
<thead>
<tr>
<th>Rating Hr</th>
<th>Min Thkns In.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Restrained Beam</td>
</tr>
<tr>
<td>1</td>
<td>5/16</td>
</tr>
<tr>
<td>1-1/2</td>
<td>7/16</td>
</tr>
<tr>
<td>2</td>
<td>11/16</td>
</tr>
<tr>
<td>3</td>
<td>1-3/16</td>
</tr>
<tr>
<td>4</td>
<td>1-5/8</td>
</tr>
</tbody>
</table>
UL Assemblies – Example 1

• And…W18x55, W/D=0.96

\[ T_1 = \left( \frac{0.82 + 0.6}{0.96 + 0.6} \right) \times 1.19 = 1.08 \]

Use 1-1/8 in

• Important note! The W18x55 has a W/D greater than that of the tested W8x28 beam, therefore the 1-3/16 in. thickness of fire protection material required for the W8x28 beam may used (larger W/D sub rule). However, the thickness adjustment equation provided a lesser amount of fire protection, so it is used. One estimate puts not using this check as adding between $0.20$ and $0.30$ per ft$^2$ of building area to new construction (2002 dollars).
UL Assemblies – Example 2

• The basic composite floor design chosen for this example is typical corner bay in a steel-framed building (see figure).

• The floor system consists of a 3¼”-thick lightweight concrete slab, with 6 × 6 – W1.4 × W1.4 welded wire mesh, on top of 3”-deep, 20-gage fluted steel deck, welded to the supporting beams.
UL Assemblies – Example 2

PROBLEM

• Determine the thickness of spray-applied fire protection necessary to satisfy the IBC requirements for Type IA Construction.
SOLUTION

- 2-hour floor construction
- 2-hour floor beams
- 3-hour structural frame (girders, spandrel beams, and floor beams with direct column connection)

- All framing connections are bolted/welded and the floor system is secured to the framing members, the floor assembly (including floor beams) and the structural frame girders and beams are classified as restrained according to Table C1.1 of ANSI/UL 263 (or Table X3.1 of ASTM E119).
For the floor assembly, the architect/engineer selects UL Design D916 since it includes composite beams, and the floor construction is consistent with that desired. No protection is required for the steel deck. The beam size specified in D916 is W8×28 (W/D=0.819) and ½” of protection is required for the 2-hour restrained assembly rating. The actual floor beams W14×26 (W/D=0.628) can be substituted in this design, and the thickness of protection required can be adjusted in accordance with the substitution equation:

\[
T_1 = \left[ \frac{W_2}{D_2} + 0.6 \right] \left[ \frac{W_1}{D_1} + 0.6 \right] \\
T_2 = \left[ \frac{0.819 + 0.6}{0.628 + 0.6} \right] 0.5 = 0.58 \text{ inches}
\]

∴ use 5/8”
For girder W16×57, spandrel beams W36×150 and W36×182, and the beam W14×26 that directly connects to the columns, a UL beam-only design must be used (to get the 3-hour). Here, UL Design N708 can be used with specified W8×28 beam size and fire protection thickness of 17/16” for the 3-hour restrained beam rating. The actual beams and girders could be substituted in this design, and the thickness of protection can be adjusted as follows:

\[
T_1 = \left[ \frac{W_2}{W_1} / D_2 + 0.6 \right] \quad T_2 = \left[ \frac{0.819 + 0.6}{W_1 / D_1 + 0.6} \right] \quad 1.4375 = \frac{2.040}{W_1 / D_1 + 0.6}
\]
UL Assemblies – Example 2

(continued)

For girder W16×57 (W/D=1.09)

\[ T_1 = \frac{2.040}{1.09 + 0.6} = 1.21 \text{ inches} \quad \therefore \text{use } 1\frac{1}{4}'' \]

For spandrel beam W36×150 (W/D=1.43)

\[ T_1 = \frac{2.040}{1.43 + 0.6} = 0.88 \text{ inches} \quad \therefore \text{use } \frac{7}{8}'' \]

For spandrel beam W36×182 (W/D=1.72)

\[ T_1 = \frac{2.040}{1.72 + 0.6} = 0.88 \text{ inches} \quad \therefore \text{use } \frac{7}{8}'' \]

For beam W14×26 (W/D=0.628) with direct column connection

\[ T_1 = \frac{2.040}{0.628 + 0.6} = 1.66 \text{ inches} \quad \therefore \text{use } 1\frac{11}{16}'' \]
UL Assemblies – Tools

Nuclear Regulatory Commission Fire Dynamics Tools (FDTs) spreadsheet 17.
Non Prescriptive options

• Reasons
  – The facility does not fall into prescriptive code requirements for occupancy
Non Prescriptive options

- Reasons
  - Designer seeks to utilize construction techniques and finish materials outside of prescriptive code to create a unique facility.
Non Prescriptive options

- Reasons
  - Because of the nature of the facility a particular prescriptive requirement does not enhance safety (or an equivalent level of safety can be provided which is more reliable and cost effective)
Non Prescriptive options

- Reasons
  - The function or use of the facility over-rides or precludes prescriptive life safety requirements.
Non Prescriptive options

- Reasons
  - Re-use of existing conditions
What tools are available?

- **Hand Calculations** – Provide conservative plume temperatures and egress times.

- **Excel spreadsheet (Transient-Based Analysis Method)** – Can provide design fire temperatures and steel iteratively calculate temperatures.

- **CFAST** – Can further refine fire based on detection, suppression, ignition of targets, natural and mechanical ventilation, can determine detector and sprinkler actuation time and provide ceiling temperatures.

- **FDS (Fire Dynamics Simulator Model)** – computational fluid dynamics modeling – Evaluates complex geometries.
Hand Calculations

Example 10.8 Maintain Tenable Conditions in Means of Egress

Using Equation (10.15), the characteristic height, $a$, can be determined:

$$a = 2.4 A_v^{0.4} H_w^{0.2} - 2.1 H_w$$

Substituting for $a$ into Equation (10.17),

$$h = 0.777 (20 \times 5^{1/2})^{1/3} (9 + 0.48)^{5/3} + 0.18 \times 20 \times 5^{1/2}$$

$$m = 20 \text{ lbs.}$$

The calculations in steps 2, 3, and 4 indicate that the axisymmetric case represents the worst-case condition.

Step 5. Statement of performance criteria. The performance criteria specifies the required performance of the smoke management system in order to achieve the stated objective(s). The mass rate of smoke exhaust should be equal to that generated in the plume, i.e., 680 lbs (step 2). Using Equation (10.12), the smoke exhaust requirement can be expressed as a volumetric rate:

$$Q = 60 \frac{m}{\rho} = 60 \times 680/0.075 = 544,000 \text{ cfm.}$$

EwingCole
Hand Calculations

HRD Based on

2000 Btu/s (7110 kW)

\[ P = 0.533 \times \frac{E_l}{1.1} = 0.533 \times \left(0.7 \times 2000 \times 2.5\%ight)^{0.4} = 9.6 \]

9.6 \leq 34' Clean Height

\[ m' = 0.022 \times \frac{E_l}{3} + 0.0042 \times E_c \]

\[ m' = 0.022 \times \left(0.7 \times 2000\right)^{0.5} \times \left(34\right)^{0.5} + 0.0042 \times \left(0.7 \times 2000\right) \]

\[ m' = 4.3 \times 7 \]

\[ Q = 60 \times \frac{m'}{3} \]

\[ Q = 60 \times \frac{60}{0.75} \]

\[ Q = 74,940 \]

EwingCole
### Transient-Based Analysis Method via Excel

#### 2003 International Building Code
Section 909.8.2 Calculation Methods for Axisymmetric Plumes

**Axisymmetric Plumes:**

The fire is burning away from walls, windows, and other factors that may affect it working in a symmetric manner.

#### STEP 1 DETERMINE VALUE OF $Z_l$ USING EQUATION 9-3

$$ z_l = 0.533 \frac{Q_c}{Q}^{2/5} $$

Where:

- $z_l = \text{Limiting flame height (ft)}$
- $Q_c = \text{Convective portion of heat release rate (70% of } Q)$
- $Q = \text{Fire Heat Release Rate (5,000 Btu/sec per IBC Section 909.9)}$

**Equation 9-3**

Therefore:

- $Q = 5000 \text{ Btu/sec}$
- $z_l = 13.9 \text{ ft}$

#### STEP 2 DETERMINE VALUE OF $Z$

Where:

- $z = \text{Height from top of fuel surface to bottom of smoke layer (ft). The bottom of the smoke layer must be maintained a minimum of 10 feet above the highest walking surface which forms a portion of a required egress system within the smoke zone.}$

Therefore:

- $z = 10 \text{ ft}$ (Determine $z$ based on configuration of atrium)

#### STEP 3 DETERMINE VALUE OF $m_p$

Where:

- $m_p = \text{Plume mass flow rate (lbs/sec)}$

If

- $z > z_l$, then:
  
  $$ m_p = 0.022 \frac{Q_c}{z_l^{1/3}} $$

- $z = z_l$, then:
  
  $$ m_p = 0.011Q_c $$

- $z < z_l$, then:
  
  $$ m_p = 0.0208 \frac{Q_c}{z^{2/5}} $$

**Equations 1, 2, 3**

Use **Equation 3** To Determine Smoke Filling Rate

#### STEP 4 DETERMINE VALUE OF $V$

Where:

- $V = \text{Smoke Rate}$
### CFAST

![CFAST Software Interface](image)

**Simulation Environment**
- **Object**: sofa
- **Type**: Constrained
- **Ignition by**: Time
- **Ignition Value**: 0
- **Peak Q**: 525,312

**File 1**
- **Compartment**: A Large Atrium
- **Type**: Constrained
- **Position X**: 25 ft
- **Position Y**: 25 ft
- **Position Z**: 0 ft
- **Ignition Criterion**: Time
- **Ignition Value**: 0 s

**Fire Object**
- **soda**

**Material Properties**
- **Urethane Insulation, Two-Part Mixture, Rigid Foam (1/2 in)**
- **Length**: 3.3025 ft
- **Width**: 6.5655 ft
- **Thickness**: 3.3025 ft
- **Mass**: 6,620.174 lb/ft²
- **Total Mass**: 317.4156 lb
- **Heat of Combustion**: 5130.975 BTU/lb
- **Heat of Gasification**: 5291.569 BTU/lb
- **Vaporization Temperature**: 86.32995 °F
- **Radiant Fraction**: 0.33

**Graph**
- **soda HRR**

**Buttons**
- **Save**
- **View**
- **Run**

No Errors
Egress Models
A new outdoor stadium facility that will have indoor amenity spaces will be constructed. Although the main use of the Stadium is an A-5 Use Group, the Stadium will also have other uses, including A-2 Dining, A-3 Lounge/Suites, B Offices and S-1/S-2 storage spaces.

To qualify as mixed use nonseparated the entire facility must be Type IA construction (due to IBC’s area limitations).
Sample variance - Issue

- The application of Type IA construction results in numerous protected structural members.

- Many members are outdoors and not subject to those same hazards as indoor members.

- Designer seeks to prove members may be unprotected because they will not reach failure during a conservative design fire.
The intent of fire resistance ratings for buildings that contain assembly occupancies at elevated locations within the building is to assure that the occupants have sufficient time to evacuate the building in a fire condition and to prevent structural collapse during firefighting operations.
Because the outdoor portions of the Stadium are not enclosed, which permits ventilation of hot gases and other products of combustion, heat will not accumulate at structural members (this is recognized by the Building Code by the permission for an unlimited area and unlimited story A-5 Stadium of non-rated construction). Outdoor structures provide an inherent level of fire protection and facilitate efficient egress and fire department operations.
• The indoor assembly spaces are protected by automatic smoke control systems.
• Significant excess exit capacity is provided for all interior assembly spaces.
• A Computational Fluid Dynamics study of a fire in the space indicates that the temperatures at the egress paths of the Suite levels above are less than 140°F, even without sprinkler activation and smoke control.
• Timed egress studies indicated that the spaces can be evacuated in less than 7.5 minutes, which is approximately 16 times the fire resistance rating of the structure within such spaces.
Let’s concentrate on the Structural aspect: Unprotected steel performance

Failure (from ASTM E119): The maximum single point temperature in a steel beam, column, or girder is 1,300 °F and the allowable average temperature in these members is 1,000 °F.
A design fire based on fire test (3.1MW) was simulated on the floor level. This fire represents a variety of fuel loads that could be expected within the club space.

Analysis of the ceiling temperature was generated by the fire model.
Sample variance – Steel performance

- Numerical Methods are available to estimate the temperature rise in steel structural elements. The equations are derived from simplified heat transfer approaches.

- Unprotected steel members: The temperature in an unprotected steel member can be calculated using a quasisteady-state, lumped heat capacity analysis. The equation for temperature rise during a short time period, \( \Delta t \), is:

\[
\Delta T_s = \frac{\alpha}{c_s (W/D)} (T_f - T_s) \Delta t
\]

Source: Society of Fire Protection Engineers Handbook, 3\textsuperscript{rd} ed.
Sample variance – Steel performance

where

- $\Delta T, = \text{temperature rise in steel (°F)/(°C)}$,
- $\alpha = \text{heat transfer coefficient from exposure to steel member (Btu/ft}^2\text{-sec)/(W/m)},$
- $D = \text{heated perimeter (ft)/(m)},$
- $c_s = \text{steel specific heat (Btu/lb °F)/(J/kg °C)},$
- $W = \text{steel weight per lineal foot (lb/ft)/(kg/m)},$
- $T_f = \text{fire temperature (R)/(K)},$
- $T_s = \text{steel temperature (R)/(K)},$ and
- $At = \text{time step (s)}$
Sample variance – Steel performance

- Using the formula an excel spreadsheet can be created with a calculation per time step (row). The resultant rise in temperature is added to the next row, etc.

\[ \Delta T_s = \frac{\alpha}{c_s(W/D)}(T_f - T_s)\Delta t \]

- OR
Fire Walls

- **Definition:** A fire-resistance-rated wall having protected openings, which restricts the spread of fire and extends continuously from the foundation to or through the roof, with sufficient structural stability under fire conditions to *allow collapse of construction on either side without collapse of the wall.* Creates separate buildings.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FIRE-RESISTANCE RATING (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, E, H-4, I, R-1, R-2, U</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F-1, H-3&lt;sup&gt;b&lt;/sup&gt;, H-5, M, S-1</td>
<td>3</td>
</tr>
<tr>
<td>H-1, H-2</td>
<td>4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>F-2, S-2, R-3, R-4</td>
<td>2</td>
</tr>
</tbody>
</table>

- a. Walls shall be not less than 2-hour fire-resistance rated where separating buildings of Type II or V construction.
- b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.4 and 415.5.
**Fire Walls (another caution)**

- **Definition:** A fire-resistance-rated wall having protected openings, which restricts the spread of fire and extends continuously from the foundation to or through the roof, with sufficient structural stability under fire conditions to *allow collapse of construction on either side without collapse of the wall*. Creates separate buildings.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FIRE-RESISTANCE RATING (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, D, E, H-4, I, R-1, R-2, U</td>
<td>3 a</td>
</tr>
<tr>
<td>F-1, H-3 b, H-5, M, S-1</td>
<td>3 b</td>
</tr>
<tr>
<td>H-1, H-2</td>
<td>4 b</td>
</tr>
<tr>
<td>F-2, S-2, R-3, R-4</td>
<td>2 b</td>
</tr>
</tbody>
</table>

a. Walls shall be not less than 2-hour fire-resistance rated where separating buildings of Type II or V construction.
b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.4 and 415.5.
c. For the purposes of determining height and area in accordance with Table 503, fire walls dividing buildings into separate buildings shall provide a 4-hour fire-resistance rating.
Fire Walls

What does this mean to you?
- Allowable building area, Table 503
- Building construction type, Table 601
- Fully sprinklered buildings

-Party Walls are a subset of Fire Wall:
  - located on a property line between adjacent buildings
  -no openings allowed.
Fire Walls

Three basic methods to achieve required stability

• CANTILEVER WALLS
• TIED WALLS
• DOUBLE WALLS
Fire Walls - Cantilever

- Design for 5 psf uniform lateral load (or seismic loads when required) from either side.
- No connections between the wall and the building frame on either side.
- Design flashing for easy release.
- Design foundation to resist the moment from the lateral load.
- Allow sufficient clearance for steel expansion from fire.
Fire Walls - Tied

Ties the roof structures on each side together such that the horizontal pull from the sagging “collapsed” members is carried by the horizontal force resisting system on the other side.

To remain stable, the pull of the collapsing steel on the fire side of the wall must be resisted by the strength of the unheated steel on the other side. Since the fire can occur on either side of the wall, the wall preferably should be located at the center of strength of the building frame.

EwingCole
Fire Walls - Tied

Tied MFL firewalls should be load bearing. In such a case, when exposure to a fire can cause bowing of the wall, the resulting lateral movement of the wall at mid-height should be accounted in the design. In other cases sagging of the steel on top of the collapsing side of the wall can also result in twisting forces at the top of the wall.

EwingCole
Fire Walls - Tied

Advantages:

• Works best when framing on either side is at same level.
• Works best when primary members are perpendicular to wall and aligned on both sides of the wall.
• Allow sufficient clearance for steel expansion from fire.

Note: If detailed without breakaway connectors, fire wall would be non-loadbearing freestanding or cantilevered.

Figure 3—Laterally Supported Non-loadbearing Fire Wall
A double firewall consists of two one-way walls back to back each tied only to its respective frame. The required rating is provided to each wall.

This type of condition is typically used where an addition requires a firewall. The existing wall, which is secured to the building frame, is altered to provide the proper fire resistance if necessary. Another firewall is then constructed close to the existing one and secured to the new building frame. When an uncontrolled fire occurs on either side of this double wall, the building frame on the fire side will collapse, pulling the wall on that side with it. The other wall, being supported by the steel on the protected side, will remain in place.
Fire Walls - Double

- May use different systems for each wall.
- Allow sufficient clearance for expansion (normal building expansion & initial fire condition).

![Diagram of Double Fire Wall](image)

*Figure 6—Double Fire Wall*
Option #1

Fire Walls - Continuity

- No opening protective required
- 3/4-hour rated opening protective required
- Upper roof
- Lower roof
- 0-hour rated exterior wall
- 1-hour rated exterior wall
- Fire wall

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.
Fire Walls - Continuity

Option #2

EwingCole
Resources


NRC FDTools – Thickness calculations, steel performance calculations


Resources

More on restrained / nonrestrained:
www.aisc.org/ContentManagement/ContentDisplay.cfm?ContentID=2796