Straightforward SPECIFICATION

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Specifying restrained classifications for fire protection in floor and roof assemblies is a more direct process than you might think.

HAVE YOU EVER BEEN ASKED whether your floor or roof is restrained or unrestrained for fire protection design?

If so, it was probably because of requirements in Section 703.2.3 in the 2015 *International Building Code* (*IBC*). The code states that the qualification of construction for the restrained classification, in accordance with ASTM E119 or ANSI/UL 263, is the purview of the registered design professional for the acceptance of the building official. Restrained construction is required to be identified on the construction documents.

When used with floor construction that is appropriately qualified as restrained, the restrained classification properly provides for life safety and property protection. The owner benefits from a lower cost for fire protection, the architect is happier because smaller clearances are required in the building finishes and reducing the quantity of any product (when possible) is a hallmark of sustainability. For all these reasons and more, it's the right thing to do.

So how can you correctly identify and properly use restrained classifications? It's actually quite easy. Following is a succession of simple tools you can use, starting with the easiest.

1. Make the question entirely irrelevant. Underwriters Laboratories (UL) Design D982 provides identical fire-protection thickness requirements for both restrained and unrestrained two-hour assembly ratings for floor construction and associated secondary members. It is based on UL tests that were carried out on structurally loaded, and physically restrained or physically unrestrained, floor assembly specimens incorporating steel beams. Therefore, the unrestrained assembly ratings in this UL design are based on the structural performance of unrestrained floor assemblies. This is in contrast to other UL designs where the unrestrained assembly ratings are derived indirectly from tests on physically restrained floor specimens. These indirect unrestrained ratings are based not on the structural performance but rather on thermal (only) performance using overly conservative temperature limits. (See the sidebar on page 56 for further information.)

The two-hour assembly ratings in UL Design D982 can be used with any UL-certified spray-applied fire-resistive material (SFRM) with thickness "sufficient to provide a one-hour Unrestrained Beam Rating." This one-hour unrestrained beam rating is a generic means of specifying the fire protection thickness required to achieve a two-hour assembly fire-resistance rating. This permits the use of any manufacturer's material with UL Design D982. It is not a reduction of the assembly fire-resistance rating from a two-hour rating because the one-hour unrestrained beam fire protection thickness was used in the UL testing that resulted in the two-hour floor assembly rating.

The UL testing that supports UL Design D982 included specimens built in both restrained and unrestrained conditions. These specimens were explicitly designed to compare the real structural performance of unrestrained specimens to the real structural performance of restrained specimens with the same fire-protection thickness. The results demonstrate that physically restrained assemblies and physically unrestrained assemblies do not differ in their fire-resistance performance with the same thickness of fire protection. For further information about UL Design D982, see **www.aisc.org/ULclarity**.

2. AISC 360 provides a simple and direct consensus approach. If you have a case that isn't covered by UL Design D982 and you must classify the construction, Appendix 4 of the *Specification for Structural Steel Buildings* (ANSI/AISC 360), available at **www.aisc.org/standards**, provides a consensus standard you can reference as your basis of classification. It says the following, in 4.3.2 and 4.3.3:

4.3.2. Restrained Construction

For floor and roof assemblies and individual beams in buildings, a restrained condition exists when the surrounding or supporting structure is capable of resisting forces and accommodating deformations caused by thermal expansion throughout the range of anticipated elevated temperatures.

Steel beams, girders and frames supporting concrete slabs that are welded or bolted to integral framing members shall be considered restrained construction.

TABLE X3.1 Guide for Determination of Restrained and Unrestrained Conditions of Construction

I Wall bearing:	
Single span and simply supported end spans of multiple bays:[A]	
(1) Open-web steel joists or steel beams, supporting concrete slab, precast units, or metal decking	unrestrained
(2) Concrete slabs, precast units, or metal decking	unrestrained
Interior spans of multiple bays:	
(1) Open-web steel joists, steel beams or metal decking, supporting continuous concrete slab[B]	restrained
(2) Open-web steel joists or steel beams, supporting precast units or metal decking	unrestrained
(3) Cast-in-place concrete slab construction[B]	restrained
(4) Precast concrete construction[B,C]	restrained
II Steel framing:[B]	
(1) Steel beams welded, riveted, or bolted to the framing members	restrained
(2) All types of cast-in-place floor and roof construction (such as beam-and-slabs, flat slabs, pan joists, and waffle slabs) where the floor or roof construction is secured to the framing members	restrained
(3) All types of prefabricated floor or roof construction where the structural members are secured to the framing members[C]	restrained
III Concrete framing:[B]	
(1) Beams fastened to the framing members	restrained
(2) All types of concrete cast-in-place floor or roof construction (such as beam-and-slabs, flat slabs, pan joists, and waffle slabs) where the floor or roof construction is cast with the framing members	restrained
(3) Interior and exterior spans of precast construction with cast-in-place joints resulting in restraint equivalent to that which would exist in condition III (1)	restrained
(4) All types of prefabricated floor or roof construction where the structural members are secured to such construction[C]	restrained
IV Wood construction:	
All types	unrestrained

[A] Floor and roof construction may be considered restrained where they are tied (with or without tie beams) into walls designed and detailed to resist thermally induced forces from the floor or roof construction exposed to fire.

[B] To provide sufficient restraint, the framing members or contiguous floor or roof construction should be capable of resisting the potential thermal expansion resulting from a fire exposure as described in X3.5 and X3.6.

[C] Resistance to potential thermal expansion resulting from fire exposure may be achieved when one of the following is provided:
(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.

▲ Table X3.1 of ASTM E119.

4.3.3. Unrestrained Construction

Steel beams, girders and frames that do not support a concrete slab shall be considered unrestrained unless the members are bolted or welded to surrounding construction that has been specifically designed and detailed to resist effects of elevated temperatures.

A steel member bearing on a wall in a single span or at the end span of multiple spans shall be considered unrestrained unless the wall has been designed and detailed to resist effects of thermal expansion.

These are clear and concise statements in the consensus standard for steel design and construction, and you can use them to properly classify the common types of structural steel construction. The *Specification* explicitly labels the most common configuration of steel construction as restrained in Section 4.3.2. This covers the majority of steel construction.

3. ASTM E119 Appendix X3 and ANSI/UL 263 Appendix C cover more cases. If you have a case that isn't directly addressed in the *Specification* or you want to use an alternative basis of classification, you can use ASTM E119 Appendix X3 and Table X3.1 (see the latter, above).

Here again, these are clear and concise statements. They are provided in the consensus standard for prescriptive fire-protection testing, and you can use them to properly classify the common types of structural steel construction. This standard is broader in its coverage and also explicitly labels types of construction as restrained and unrestrained. It covers all steel construction.

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Note also that ANSI/UL 263 is a parallel consensus standard to ASTM E119 and provides similar guidelines in its Appendix C. Both of these documents are directly referenced in *IBC* Section 703.

4. Use the seminal juried paper that directly addresses this topic. The information provided in the foregoing consensus standards is supported by an extensive and substantial list of references. These references provide direct and quantitative measures of restraint. They report on and conclude the results of many decades of large-scale fire tests, detailed experimental investigations and extensive research and analysis. The picture they paint is clear and incontrovertible. Your needs will be well served by an *Engineering Journal* paper from the second quarter 2001 issue: "Restrained Fire Resistance Ratings in Structural Steel Buildings" (visit **www.aisc.org/ULclarity** to view it).

Two of the conclusions provided in this paper are particularly relevant to this article:

> "All steel beam connections to other structural steel members exhibit both axial and rotational restraint. The least stiff connection typically used for steel framed construction (such as a three-bolt single plate connection) is adequate to develop restrained performance."
>
> "Conclusions drawn from the fire research and computer modeling that have been performed by various agencies, including Underwriters Laboratories, Inc., support the conclusion that a restrained assembly classification and fire protection design is most appropriate for steel beam floor and roof assemblies, and verify the guidance contained in ASTM E119 ...Appendix X3."

As before, these are clear and concise statements that you can use to properly classify structural steel construction.

The paper is the seminal reference on restrained and unrestrained classifications because it concatenates the results and conclusions presented in all the other references. It provides a complete review of the historical developments related to restrained and unrestrained classifications and explains these classifications. It also serves as the singular reference you can read to gain a complete understanding of the subject.

What Are Restrained and Unrestrained Ratings?

UL and other fire testing agencies conduct their furnace tests following ASTM E119 or ANSI/UL 263. These standards provide alternatives that the client can choose, and the most fundamental choice in furnace testing is whether to construct the test specimen as restrained or unrestrained.

When a client chooses to construct and test a restrained assembly, it results in two assembly ratings:

- A restrained assembly rating is determined by the rise in temperature at the slab top surface, the prevention of flame passing through the assembly or the ability to carry the load. For steel-framed floors with concrete slabs, the restrained assembly rating is usually recorded when the slab top surface temperature criterion is reached or flame penetration occurs, because load-carrying capacity typically is not yet reached when these occur.
- An unrestrained assembly rating is inferred based on measured beam temperature, although the beam is physically restrained in the test. When the beam temperatures reach 1,100 °F average at any beam section or 1,300 °F at any one location, the time is recorded as the unrestrained assembly rating.
- Also note that there is an additional safeguard that is specified for the restrained rating: It cannot be more than twice higher than the unrestrained rating determined based upon the beam temperature criteria, regardless of the actual performance in the test.

When a client chooses to construct and test an unrestrained assembly, it results only in an unrestrained assembly rating. In this case, the unrestrained assembly rating is determined by the same temperature, flame and structural performance criteria described above for the restrained assembly rating, not as an alternative inferred from beam temperatures. For steel-framed floors with concrete slabs, unrestrained assembly ratings inferred from a restrained assembly test are always more conservative compared to unrestrained assembly ratings determined from an unrestrained assembly test.

AISC and AISI found the same performance in the direct comparison of the UL tests constructed in both conditions that support UL Design D982. The National Institute of Standards and Technology (NIST) found that the restrained assembly rating was *conservative* compared to the unrestrained assembly rating in the comparative tests performed as part of their study of the World Trade Center. Other research and testing of steel construction shows this has been well known for a long time. (See the 2001 *Engineering Journal* paper "Restrained Fire Resistance Ratings in Structural Steel Buildings," mentioned in the main article.)

Moreover, it is interesting to note that this also has been observed in concrete fire tests as well. See the following:

> Carlson, C. C., Selvaggio, S. L., Gustaferro, A. H., "A Review of Studies of the Effects of Restraint on the Fire-Resistance of Prestressed Concrete," Feuerwider-stansfahigkeit von Spannbeton, Ergebnisse einer Tagung der F.I.P. in Braunschweig, Juni 1965. Wiesbaden-Berlin, 1966, p. 32-42.
>
> Issen, L. A., Gustaferro, A. H., Carlson, C. C., "Fire Tests of Concrete Members: An Improved Method for Estimating Thermal Restraint Forces," Fire Test Performance, ASTM STP 464, ASTM, 1970, pp. 153–185.

This underscores the overly conservative nature of the inferred unrestrained assembly ratings provided in all UL Designs other than UL Design D982. This conservatism was noted in the aforementioned *Engineering Journal* paper: "The unrestrained assembly fire-resistance rating for structural steel beam floor and roof systems, based on ASTM E119 temperature criteria only, has no relevance to the behavior of these systems under uncontrolled fires in real buildings."

▲ The two-hour assembly ratings in UL Design D982 can be used with any UL-certified spray-applied fire-resistive material (SFRM) with thickness "sufficient to provide a one-hour Unrestrained Beam Rating."

And as a paper published in a peer-reviewed and juried journal, it is authoritative. Furthermore, the bibliography assembles the additional body of supporting work. It is substantial and definitive should you want further detail or support of a specific point.

5. Follow the further guidance provided in the other relevant documents. Other AISC publications relate and provide similarly clear and useful recommendations regarding classification, as well as supporting information. Additionally, other organizations have published similar documents of their own. Following is a summary of the available documents and their content relevant to this article.

AISC has published AISC Design Guide and Facts documents on fire protection and design. Design Guide 19: *Fire Resistance of Structural Steel Framing* is available at **www.aisc.org/dg**, and Facts for Steel Buildings Number 1: *Fire Facts* is available at **www.aisc.org/facts**.

- The Design Guide states:

  "Most common types of steel-framed construction are classified as thermally restrained. Appendix X3 of ASTM E119 lists the few instances where individual steel beams and girders, or steel-framed floor and roof assemblies, are classified as unrestrained."

- The Facts document states:

  "Appendix X3, Table X3.1 of ASTM E119 provides guidance on the classification of beams, floor and roof systems in construction as restrained or unrestrained ...in most practical cases, structural steel beams and steel-framed floor systems within steel-framed buildings are classified as restrained."

The Council of American Structural Engineers (CASE) has published its own guideline document: *Structural Engineer's Guide to Fire Protection*. This is a very useful summary document written primarily for the structural engineer of record. It states the following, specifically related to restrained and unrestrained classifications:

> In structural steel construction, the "thermal restraint" developed under fire conditions is a combination of two primary effects:
>
> 1. Resistance to axial thermal expansion provided by the surrounding framing and floor slab or roof deck
> 2. Resistance to rotation of the ends of the beams and girders. This restraint is influenced by connection stiffness, girder or column stiffness and interaction of the beams with composite or non-composite components of the floor or roof construction
>
> Both modes of restraint occur in steel-framed buildings and they both contribute to the fire resistance of a structural steel-supported floor or roof system. Indeed, there is strong evidence that, of the two modes, rotational restraint is the more significant. Even minimal rotational restraint provided by simple connections is effective in achieving "thermally restrained" performance. This suggests that calculation (documentation) of the amount of thermal restraint that exists in a structural steel frame building is unnecessary.
>
> …information about the test frame stiffness has sometimes been misinterpreted. It has been suggested that a building structure must have stiffness greater than that of the test frame to qualify as thermally restrained. This is an erroneous interpretation.

These documents all add to the clarity, usefulness and appropriateness of restrained classifications in steel construction. They also demonstrate a breadth and variety of organizations and entities that are consistent on this subject. In fact, we are not aware of a single credible technical document that contradicts the usefulness and appropriateness of restrained classification.

What if Someone Challenges You?

It's clear that there are those who are committed to their belief that unrestrained classifications should be used in all cases. They continue to maintain this belief even in the face of the mountain of available proof to the contrary, including in the aforementioned information. They do so without a shred of research, testing or other proof to support their case. This is why their arguments are based only on confusing statements—even when there is no confusion.

As summarized in the sidebar, UL will perform tests in the restrained configuration or in the unrestrained configuration. However, only AISI (American Iron and Steel Institute) and AISC have ever used the unrestrained configuration to establish a UL Design. That's right. All those who advocate that steel must be classified as unrestrained do not conduct their own tests in the very condition they insist is more appropriate as a classification. If that's what they believe, they should be consistent and conduct their tests using specimens built in the unrestrained condition. We believe this speaks volumes about their position.

In the absence of any technical basis, there have been some attempts to use as "proof" International Code Council (ICC)

A floor assembly undergoing a fire test.

An SFRM-protected floor assembly following a fire test.

interpretation letters written to fire-protection manufacturers. All such letters we've seen say the letter is not an ICC position and cannot be published in any form, implying such approval by the ICC. If you are shown such a letter, please send a copy to the AISC Steel Solutions Center (**solutions@aisc.org**).

Simple and Sound

This article provides five clear, simple and technically sound bases by which you can properly classify structural steel floor and roof construction as restrained or unrestrained for fire-protection design. If you are the responsible design professional, it provides the basis you need to satisfy the requirement that *IBC* Section 703.2.3 places upon you as you specify a restrained classification on the design drawings. If you are the building official, it also provides a basis upon which you can accept a restrained classification.

It is clear that a restrained classification is almost always the correct classification. The exceptions that require an unrestrained classification also are well defined in the foregoing information. ■