Fireproofing Steel Structures

Restrained vs. Unrestrained Assemblies

By Michael Giardinelli

One of the most critical issues in the fire protection industry today is the topic of *Restrained vs. Unrestrained* assemblies. It is important because misunderstanding of this topic can lead to inadequate fire protection and premature failure of the protected structural steel framed building. Many are unaware that the fire test procedure used to design passive fire protection for structural steel recognizes two different forms of end support for beams tested in roof and floor assemblies. The ends of the beams can be tested in a fully restrained or fully unrestrained condition.

***Poor Performance**: Office Building Fire. Beams and Girders sagging severely. Result of intense heat over a number of hours.*

From a structural engineer's point of view, the most common forms of steel framed construction are considered structurally restrained to some degree, and certainly at ambient temperatures, this is correct. The main question, however, is whether the same assembly is *Thermally Restrained* at elevated temperatures as defined by Underwriters Laboratories Inc (UL). In other words, will the structure remain restrained and be able to support the design loads as the steel temperature approaches 1100˚F. When worded in this fashion, few architects or engineers are able to answer this question with an affirmative yes.

In a truly restrained assembly, the structure surrounding the floor beams (*primary framing members and adjacent floor areas*), will be able to resist the thrust placed upon them caused by the thermal expansion of the floor beams. Since the beams in a restrained assembly, have a rating less than the assembly rating itself, they will start to fail in a particular mode that still allows the structure to support the design load, as well as prevent the passage of heat to the unexposed surface of the floor or roof.

An assembly that is *Structurally Restrained* at ambient temperatures, but not *Thermally Restrained* under fire conditions, may not be able to support the design load of the structure for the required period of time, or may transfer too much heat to the unexposed surface of the assembly. To understand the difference between *Restrained and Unrestrained* assemblies, you must first understand a little about the role of spray applied fireproofing, how it works and how it is tested.

Obviously, structural steel is a non-combustible material; however, the high-sustained temperatures of a fire can severely damage unprotected steel. Structural steel will lose approximately 50% of its load carrying capacity as temperatures approach 1100˚F. Fireproofing works by encasing the steel and insulating it, keeping the steel temperature below the point where design strength is compromised. In order to determine the amount of fireproofing required in to achieve this goal, UL tests fireproofing products in accordance with ASTM E119 (UL 263). The results of the test are published in the UL Directory, which specifies the thickness and density of the material, as well as how the assembly is to be constructed in order to achieve various levels of hourly rating.

It is important to note that the ASTM E119 test procedure was developed in 1918, and although construction types and building contents have changed over the years, with the exception of a few minor refinements, the basic ASTM E119 overall test criteria has not changed. ASTM E119 is a standardized test method, which provides a means by which the performance of one material can be compared with that of another, under very defined conditions.

***Better Performance**: Office Building Fire. Beams Girders and Columns remained intact. Some fireproofing removed from the steel as a result a result of the stream of water from the Fire hoses, but the building survived the fire.*

Many designers are under the impression that if an assembly on a project site is sprayed in accordance with a UL tested two-hour assembly, that the structure will remain intact for two hours, sustaining little or no damage. This is not necessarily true. How well an actual structure performs relative to the design assembly greatly depends on how closely the fire mimics the ASTM test standard, the actual condition of restraint, and the amount of fireproofing actually applied to the steel. Unfortunately, the amount of fireproofing required to properly protect a building is the subject of some debate.

Classifications

Many structural steel framed buildings are designed assuming them to be *"Thermally Restrained"*, with little or no understanding of what this actually means.

The ASTM E119 standard used by Underwriters Laboratories to test fireproofing materials defines four hourly classifications for floor ceiling and roof ceiling assemblies. The four classifications are:

- Restrained Assembly
- Unrestrained Assembly
- Unrestrained Beam
- Restrained Beam

There is confusion in the industry regarding beam ratings versus assembly ratings. In short, the thickness of fireproofing required to achieve a two-hour beam rating is an amount that will prevent the beam from reaching 1100˚F for the required hourly rating, in a laboratory condition. An assembly rating, however, is concerned with how the entire floor or roof construction performs during a fire, and how well it supports the design load. The pass-fail criteria are different for an assembly rating versus a beam rating.

Depending on whether or not the assembly is considered to be *Restrained or Unrestrained*, the beam rating may or may not equal the assembly rating. A Restrained Assembly rating, Unrestrained Assembly rating and an Unrestrained Beam rating are all determined from the same ASTM E119 test. A Restrained Beam rating is obtained from a separate test and not discussed here.

The ASTM E119 criteria for the test, more or less, are as follows:

1. The specimen shall sustain the applied load during the classification period.
2. The unexposed surface temperature shall not ignite cotton waste nor exceed 250˚F above ambient.
3. No steel temperature at any point on the steel shall exceed 1300˚F.
4. The average steel temperature at any location shall not exceed 1100˚F.

For an Unrestrained Assembly rating, the temperature limitations on the beams are in effect for the full hourly classification period, which means, provided items 1 and 2 are not violated, the test will continue until the temperature criteria is breached (items 3 and 4). Once the temperature criteria are exceeded, the thickness of fire protection required for an Unrestrained Assembly rating and an Unrestrained Beam is determined for 1, 2, 3 or 4 hours.

In order to achieve a Restrained Assembly rating, the same test continues for a period up to twice the hourly-unrestrained rating of the beam, or until the temperature on the unexposed surface exceeds 250˚F above ambient temperature (the temperature at which cotton waste is ignited), or the assembly can no longer support the design load. This means that a two-hour restrained assembly may have beams in the assembly with a 1-hour unrestrained rating. In the real world, these same beams would likely experience significant distortion and sagging in the first hour of a fire. Despite the condition of the beams however, as long as the assembly does not collapse or the temperature criteria for the unexposed surface is not violated, the design meets the UL requirements of a *Thermally Restrained Assembly*.

In truth, *Restrained Assemblies* will always experience greater structural damage than *Unrestrained Assemblies*, simply because the beams do not have the same amount of fire protection on them. In a two-hour

Appendix C of ANSI/UL 263 defines Restraint as follows: *"Floor-ceiling and roof-ceiling assemblies and individual beams in buildings shall be considered restrained when the surrounding and supporting structure is capable of resisting substantial thermal expansion throughout the range of anticipated elevated temperatures. Construction not complying with this definition is assumed to be free to rotate and shall therefore be considered as unrestrained"*. The amount of stiffness built into the UL test frame is 850,000 kip-inches and 700,000 kip-inches along the 14 foot and 17 foot sides, respectively. Underwriters Laboratories comments on the stiffness provided by the UL test frame and notes that the designer may determine that a different amount of restraint may be required than the amount provided by the test assembly. The International Building Code (IBC) position on restraint is as follows: *"Assemblies tested under ASTM E119 shall not to 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 restrained classification in accordance with ASTM E119. Restrained construction shall be identified on the plans."*

***UL**: View of a floor assembly being lowered onto the UL Test Chamber.*

Restrained Assembly, the hope is that although the floor beams are likely to fail prior to two hours, the overall floor assembly will not collapse. The problem is that the size and construction of the test assembly may not be representative of the actual construction within a building. For instance, the UL test assembly is 14 feet wide by 17 feet long, much smaller than a typical bay in a building. Will a 30-or 40-foot bay meet the requirements of Underwriters Laboratories for a *Thermally Restrained Assembly*? Will the floor or roof assembly be able to support the required design loads for the specified period, as well as prevent the passage of heat to the unexposed surface? The reality is that actual construction may not match the UL tested condition of a *Truly Assembly Thermally Restrained*.

Recommendations

1. To determine if an assembly is Restrained or Unrestrained, knowledge of the building code and the UL Directory is imperative. Section 714.1 of the 2003 International Building Code states: "*The fire-resistance rating of the structural members and assemblies shall comply with the requirements for the type of construction and shall not be less than the rating required for the fire resistance rated assemblies supported.*" This means the beams in a two-hour rated assembly must be protected for a full two hours. Unfortunately, this particular paragraph in the code is often overlooked or misinterpreted.
2. The proper way to fireproof a Restrained assembly is to fire proof the primary framing members to the full hourly classification required by code in accordance with a "N" or "S" series beam only design using the Unrestrained criteria. The floor or roof beams can then be protected using the same UL designs, but sprayed to the Restrained criteria.
3. To simplify the procedure and insure the proper amount of fire protection under any condition, simply designate fire protection to be applied in accordance with the unrestrained thickness requirements.

In summary, there are a number of reasons to designate assemblies as Unrestrained:

a. There is a lot of confusion over what constitutes a *Thermally Restrained* assembly. Many Architects, Engineers, Building Code Officials and Fireproofing Contractors simply do not understand the difference between Restrained and Unrestrained Assemblies, or how to design or protect them. Many decisions designating assemblies as Restrained are based on opinion papers and commentaries which conclude that all steel framed structures are restrained. Yet, UL and other documentation on restrained assemblies urge designers to perform calculations to determine restraint and exercise caution in designating assemblies as Restrained. The IBC code states that assemblies can be designated as Restrained provided the registered design professional can prove it is so. Elsewhere in the code, it also states that the beam rating must equal the assembly rating, which negates the use of two-hour Restrained Assembly Ratings with 1-hour Unrestrained Beams.

b. There is confusion over the type of damage likely to be sustained in a Restrained Assembly. Many designers believe that if an assembly is truly restrained, it will perform equally as well as an unrestrained assembly. This is not the case. When deciding to designate an assembly as Restrained or Unrestrained, among other things, the designer should factor in the use of the building, the risk to the occupants and the expectations of the owner.

c. UL 263 (ASTM E119) may not be representative of today's actual fires. Just because a floor is sprayed in accordance with a two-hour rated UL assembly, does not mean it will actually sustain the loads for 2 hours. Combine this with the possibility of improperly protected floor beams and primary members, and the results in an actual fire could be devastating.

d. An Unrestrained thickness does a better job of protecting steel simply because it provides for more fireproofing on the steel. The cost differential between a properly protected Restrained Assembly and an Unrestrained Assembly is negligible. However, the value afforded by the added assurance of proper protection is immense.

In short, designating assemblies as Unrestrained will insure you meet the intent of the code in any part of the country, limit liability, and provide the best possible protection for the building required by the code.▪

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