

Hot Topic

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A recent change in the UL *Fire Resistance Directory* allows designers to adjust the thickness of spray-applied fire protection materials for both restrained and unrestrained beam ratings.

For years, some developers hoping to specify structural steel have been faced with an obstacle—the high cost of fire protecting steel to meet the requirements of building codes and the Underwriters Laboratories (UL) *Fire Resistance Directory*. But a recent change in the UL *Fire Resistance Directory* now will help reduce the cost of fire protection for structural steel. A change in the 2003 UL *Fire Resistance Directory*, Design Information Section, Part IV, Item 6, “Adjustment of Thickness of Spray-Applied Fire Resistive Materials for Restrained and Unrestrained Beams” now permits the substitution of restrained beams as well as unrestrained beams when using the equation to determine the appropriate thickness of spray-applied fire protection materials required for given beam sizes.

Engineers say this means that the cost of using structural steel in projects that require fire protection will drop. “The basic difficulty was that the application of the thickness adjustment procedure in the old version was limited to unrestrained beam ratings,” said Farid Alfawakhiri, AISC senior fire design engineer. “Designers now can use restrained designs more often for a reduction in the cost of fire protection. A restrained vs. unrestrained rating often means a difference of 25 cents to 30 cents per square foot of building area; and in a competitive en-

vironment, that can make the difference of winning or losing a project to concrete. This is another step to making steel more competitive.”

UL and the American Iron and Steel Institute (AISI) developed the original equation in 1984 based on statistical correlation of unrestrained rating results from tests on restrained beams. “There was a need in the industry to find a way to go from the UL report for specific beam sizes to the actual sizes used in construction,” said Robert

greater structural capacity under fire exposure than unrestrained beams. “It has been generally understood by specialists that the formula could be applied to restrained beams,” Alfawakhiri said. Nonetheless, the relevant text as printed in Item 6 of the UL Directory from 1993 to 2002, limited the application to unrestrained beams only. “The original research that the industry did had been clear—that you could use it for restrained and unrestrained beams.” Wills said. “But the equation was worded differently in the UL Directory.”

Engineering firm Structural Affiliates International, Inc. of Nashville, TN helped spearhead the effort to conduct further in-depth research on questions of fire engineering. “About five years ago, we discovered a real disparity in the cost of buildings depending upon whether or not the architect specified a restrained or unrestrained system,” said SAII Chief Operation Officer John L. Ruddy, P.E. “On one particular project, the structural cost increased substantially between two phases of a project because the architect changed from thermally restrained to an unrestrained assembly. This started us on a path of investigation, and we realized that the cost increased because the unrestrained specification doubled the thickness of the fireproofing required—causing what appeared to be an unnecessary increase in the cost of steel.”

Using a restrained rating vs. an unrestrained rating often translates to a savings of 25 cents to 30 cents per square foot of building area.

Wills, P.E., AISI regional director of construction codes and standards.

The terms “restrained” and “unrestrained” refer to whether or not beams are positioned in frames that restrict their thermal expansion. Thermally restrained beams require less spray-on fire protection material than unrestrained ones because they exhibit

Design Example

Beams/Girders within a Restrained Floor Assembly

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. The section sizes for beams and girders are shown in the figure.

PROBLEM

Determine the thickness of spray-applied fire protection necessary to satisfy the International Building Code requirements for Type IA Construction.

REQUIRED

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

SOLUTION

Since 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 Item 6 equation:

$$T_1 = \left[\frac{W_2 / D_2 + 0.6}{W_1 / D_1 + 0.6} \right] T_2 = \left[\frac{0.819 + 0.6}{0.628 + 0.6} \right] 0.5 = 0.58 \text{ inches} \quad \therefore \text{use } 5/8"$$

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. 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.

$$T_1 = \left[\frac{W_2 / D_2 + 0.6}{W_1 / D_1 + 0.6} \right] T_2 = \left[\frac{0.819 + 0.6}{W_1 / D_1 + 0.6} \right] 1.4375 = \frac{2.040}{W_1 / D_1 + 0.6}$$

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)

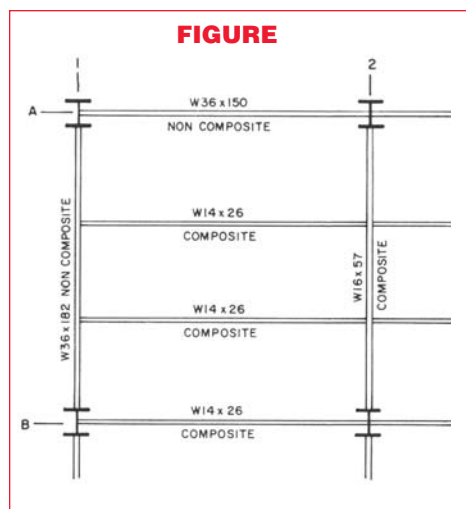
$$T_1 = \frac{2.040}{1.43 + 0.6} = 1.00 \text{ inches} \quad \therefore \text{use } 1"$$

For spandrel beam W36×182 (W/D=1.72)

$$T_1 = \frac{2.040}{1.72 + 0.6} = 0.88 \text{ inches} \quad \therefore \text{use } 7/8"$$

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

$$T_1 = \frac{2.040}{0.628 + 0.6} = 1.66 \text{ inches} \quad \therefore \text{use } 1\frac{11}{16}"$$



Since then, SAII has worked with AISC to mobilize others in the steel industry to take a closer look at fire engineering. "The approach to fire protection in steel buildings is somewhat prescriptive—designers and building codes follow what's been done in the past," Ruddy said. "We hoped to find a rational reduction to the amount of fire protection on the steel. Why put twice as much fire protection on the steel if the system can perform using the thickness that is associated with the classification of restrained?"

Ruddy says one problem with limiting the applicability of the Item 6 adjustment equation was that unrestrained ratings are based on temperature measurements, rather than the load-bearing capacity limits of structural systems exposed to high temperatures. "The basis for the unrestrained rating is the time it takes for a beam to reach 1100°F," Ruddy said. "It has nothing to do with how well an entire system restrains the load—it's just a temperature measurement. It's possible for the system to perform for two hours, even if the beam reaches the temperature after one hour. The beam can get hotter as long as the system performs."

When the AISC Fire Safety Engineering Committee was formed in May 2001 to develop and promulgate rational fire design practices, UL representatives joined the committee and

agreed to conduct a study on the applicability of the Item 6 equation to restrained and unrestrained systems. "We received questions from architects and engineers about the equation," said UL Senior Staff Engineer Robert Berhning. "But until AISC approached UL, we could not fund further research."

The study was conducted from July 2002 until December 2002. "We wanted to look at the feasibility of extending the equation or developing a new equation, to ease its use and reduce confusion," Berhning said. The study concluded that the Item 6 equation could be applied to both unrestrained and restrained ratings, given that "when used to adjust the material thickness for a restrained beam, the use of this procedure is limited to steel sections classified as compact in accordance with the Specification for the Design of Structural Steel Buildings by the American Institute of Steel Construction, Load and Resistance Factor Design, Third Edition [The AISC allowable stress design (ASD) specification's classification of compact sections applies here as well as the LRFD specification's classification]."

The equation restricts the use of steel sections in restrained systems to compact shapes, since they tend to yield before buckling, which can assist in limiting a premature failure of the load, Ruddy said.

The change could help clarify Item 6 for engineers. "This eliminates the

unnecessary confusion that existed before, as well as the use of unnecessary amounts of fireproofing," Alfawakhiri said.

The change might also help eliminate confusion about codes that reference the UL Directory. "I think we can now correct some of the confusion in the IBC and the ASCE 29 Fire Standard, since some of the ambiguity in the UL directory is also reflected in those documents," Wills said. "This will be beneficial for the steel industry, and will get us back to where we should have been to begin with; but we need to make sure to educate designers how to use the equation."

Ruddy says that the change will help engineers move towards a more analytical approach to fire protection. "The process of agreeing on a rational approach to fire protection is going to take a long time," he said. "While we work on developing equations that engineers are comfortable with, we'll continue to use prescriptive approaches; but we don't want to penalize structural steel with excessive amounts of fire protection."

An updated version of Item 6 is available on UL's web site, and can be linked to from AISC's web site. Visit www.aisc.org/fire, and click on the link to the 2003 UL Fire Resistance Directory Design Information Section, listed under "Other Resources" on the lower right side of the page." ★