Following The World Trade Center disaster, a review of current design practices has commenced with hope that out of the tragedy something may be gleaned that could influence more effective new building designs. Fireproofing is a legitimate area of focus. There is little debate that a more rational approach to fire protection is restrained against the test frame. However, a single test is used to determine two conditions of thermal restraint of the structural system, restrained and unrestrained. Thermal restraint is defined as the condition when the surrounding or supporting structure is capable of resisting substantial thermal expansion throughout the range of anticipated elevated temperatures. The supports of a thermally unrestrained condition are free to rotate and expand. Except in unusual conditions, steel framed structures are thermally restrained [2].

A fire is ignited within the furnace and controlled to follow a standard time temperature relationship (standard fire). The fire is continued and the thermal couple readings are recorded. The time when either the average steel temperature reaches 1100°F or any one location reaches 1300°F is recorded. This time establishes the unrestrained assembly and unrestrained beam rating as long as the temperature on the non-fired side has not been raised more than 250°F or cotton balls on the non-fire side have not ignited. The standard fire is continued and a second time recorded when any one of the following conditions occurs; the load can no longer be supported, the temperature on the non-fired side has raised more than 250°F or cotton balls on the non-fire side have ignited. If this second time exceeds twice the unrestrained time then twice the unrestrained time is recorded as the restrained assembly rating otherwise the second time is recorded as the restrained assembly rating. A provision in establishing the restrained rating of an assembly is that the temperature limits (1100°F and 1300°F) not be exceeded at one-half the restrained rating time or one hour whichever is greater. Therefore, for the case of a one-hour fire resistance rating, the spray-applied fire resistive material thickness is independent of a restrained or unrestrained rating.

The plot of temperature versus time depicted in Figure 1 is a simplified graphic of the application of ASTM E119 in determining the fire resistance rating for restrained and unrestrained assemblies.

BEAM SUBSTITUTION

The beams used in the fire test will seldom match the steel sections used in the actual building. However, the thickness of spray-applied fire resistive material applied to the test beam can be used as a basis for calculating the thickness to be used on the substitute beam. If the rate of temperature increase in a substitute beam can be confirmed to be equal to or less than the rate of temperature change in the test beam, the performance of the assembly, with a substitute beam, will be as good as or better than the tested assembly.

The rate of temperature change in a body is a function of its mass and the area of its surface exposed to the temperature difference. Therefore, a factor influencing a steel member's fire resistance is W/D where: W = the weight per unit length of the member and D = the perimeter of the member exposed to the temperature differential. The larger the value of W/D, the slower the rate of temperature change. Thus, if the steel section to be substituted for the tested section has a larger W/D than the W/D of the tested beam a reduced thickness of spray-applied fire resistive material can be used and the substituted beam will gain heat at a rate less than or equal to that of the test beam.

If the W/D ratio of the substitute beam is less than the W/D of the tested beam, an increase in the fire protection thickness can be determined to assure that the thermal performance of the substitute beam is equal to that of the tested beam.

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intended construction and the details of the slab construction are important, not only to model the slab's resistance to heat transfer, but also to appropriately model the dissipation of heat away from the beam. Several UL tested assemblies are indicated in Figure 2. Each of these designations can be referenced to provide 1, 1½, 2, and 3 hour fire resistance ratings depending on the slab construction and the thickness and type of fire protection. If composite beams are used in the test, either composite or non-composite beams may be used in the actual structure. However, if non-composite beams are used in the test, composite beams cannot be used in the structure. The UL designations tabulated in Figure 2 represent systems that do not rely on the ceiling for fire resistance and among rating can be achieved with 1 in. of spray-applied material on the test beam and a 3-hour unrestrained beam rating can be achieved with 1 9/16 in. spray-applied material on the test beam. The restrained assembly rating remains at 2 hours in spite of the increase in beam protection from 3/8 in. to 1 9/16 in. for the all fluted deck condition. However, a 1 hour unrestrained beam rating is an acceptable component of a 2-hour restrained assembly rating with 3/8 in. of spray-applied fire resistive material on the W8×28 test beam.

A 2-hour fire resistance assembly rating with lightweight concrete has an associated 1-hour unrestrained beam rating with a 3/8 in. thickness of spray-applied fire-resistive material applied to the W8×28 test beam. The *W/D* ratio for the W8×28 is 0.80. The required material thickness for the W16×26, W21×44 and W24×55 are calculated as follows:

W16×26 *W/D* = 0.55

W21×44 W / D = 0.73

W24×55 W / D = 0.82

The approximate quantity of spray-applied fire resistive material required for the horizontal steel framing can be calculated considering a 30’ length (1 bay) by 120’ width (4 bays) of the building. In that 3,600 ft^2 section there are sixteen W16×26 beams, three W21×44 girders and two W24×55 spandrels.

EXAMPLE 1 SUMMARY

<u>Sprayed Material Quantity</u>

W16×26 1/2”
0.50” × 3.89 sf / ft × 30 ft × 16
= 933.60 board ft

W21×44 7/16”
0.438”× 4.94 sf / ft × 30 ft × 3
= 194.51 board ft

W24×55 3/8”
0.375”× χ 0.025P3333 TΔ 0 Tω (ιγτTχ 0.35871–91.8675 Tμ (3σ.τεδ ασ)]Tϑ –)–2/Φ7 73

N for floor conditions and Series S for roof conditions. In order to use the beam only test with an assembly test, restrictions are imposed:

1. The floor or roof construction of the beam-only design must have a lower capacity for heat dissipation than the floor or roof construction of the assembly.
2. The spray-applied material of the beam-only test must be the same as the spray-applied material of the assembly test.

The UL listing N823 beam-only test meeting this criteria for substitution in the UL D902 assembly test is indicated in Figure 7.

EXAMPLE 2

Again consider the construction depicted in Figure 4 but requiring a Type 1A construction classification as defined by IBC. Under Type 1A construction, the structural assembly is required to provide a 2-hour fire resistance rating and the structural frame is required to provide a 3-hour fire resistance rating. The structural frame is defined as the columns and girders, beams, trusses and spandrels having direct connection to the columns.

The $2^1/_2$ in. concrete slab with a density of 102 pcf satisfies the lower capacity for heat dissipation criteria considering the $3^1/_4$ in. lightweight slab that is part of the D902 assembly. The spray-applied material in the beam-only test is the same as the spray-applied material in the assembly test. Therefore, this beam-only test can be used to determine the protection required to make the structural frame comply with a 3-hour rating in an assembly having a 2-hour rating.

The test beam in both conditions is a W8×28 and $1^1/_4$ in. of spray-applied material will produce a 3-hour restrained beam rating. The *W/D* of the test beam is 0.80. The spray-applied fire resistive material thickness requirements for members that have *W/D*