Fire Resistance

By Farid Alfawakhiri, Ph.D., P.Eng. and Charles J. Carter, P.E., S.E.

Trusses made of structural steel shapes are the common framing choice in structural systems that span over long distances or support heavy loads. For many occupancy groups, trusses are utilized as a means of achieving a high degree of spatial flexibility. As a result, certain trusses support large portions of buildings and are deemed to be of "critical" structural importance. Adequate attention is therefore essential to the fire resistance aspect of truss design.

This article discusses practical methods of fire protection with focus on three types of trusses:

- Typical truss systems, usually consisting of regularly spaced trusses supporting one floor or one roof.
- Staggered truss systems – consist of story-high trusses each usually supporting two floors (or one floor and one roof) at top and bottom chord levels.
- Transfer truss systems that support walls or columns above the truss, or support tension elements below the truss.

This article does not address the fire protection of pre-engineered lightweight open-web joist systems. Technical Digest #10 (July 2003) *Design of Fire Resistive Assemblies with Steel Joists* published by the Steel Joist Institute (**www.steeljoist.org**) covers this topic.

# of Steel Trusses

Fire Resistance Requirements

The applicable building code of the project jurisdiction (municipality, state, federal agency, etc.) specifies the fire resistance requirements. In most cases, jurisdiction codes are based on a model building code, such as the International Building Code (IBC). Currently, the 2000 edition of the IBC is probably the most widely adopted model code in the US, and therefore, it is referred to in this article.

The following factors are considered in the determination of the required fire resistance for floors, roofs and structural frames:

- Building uses and occupancies
- Building height and area
- Combustibility of construction
- Accessibility by fire department
- Distance from other buildings
- Presence of sprinklers and other active fire protection systems

IBC Table 601 specifies the fire resistance requirements, in terms of hourly ratings, through the classification of five types of construction. As a non-combustible material, structural steel is mostly used in non-combustible construction of Type I and Type II. The relevant IBC fire resistance requirements for floor, roof and frame construction are listed in *Table 1*. Construction Types III, IV and V allow heavy timber and combustible materials.

"Variations of fire-related risks… are addressed through the use and occupancy classifications."

It should be noted that the second footnote under *Table 1* (referred to as the "20 feet rule") often applies to roof trusses that span over high spacious premises. This provision is in recognition of the very low probability of hot post-flashover fires in spacious premises with low levels of combustible contents.

Normally, higher levels of fire resistance are required for larger and taller buildings, built of combustible materials, having limited access, located close

Table 1
Required Fire Resistance Ratings from IBC Table 601 (hours)

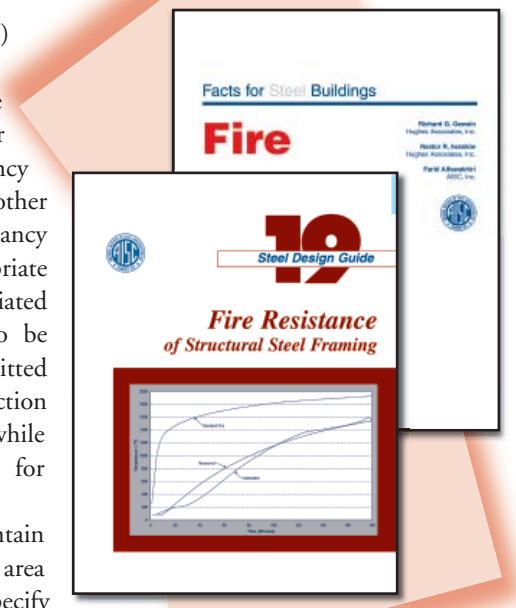
Construction Type		Structural frame,*** including columns, girders, trusses	Floor Construction, including supporting beams and joists	Roof Construction, including supporting beams and joists
Type I	A	3*	2	1.5**
	B	2*	2	1**
Type II	A	1	1	1**
	B	0	0	0

* Fire-resistance rating of structural frame is permitted to be reduced by 1 hour where supporting a roof only.
** Except in buildings of groups F-1, H, M and S-1 occupancies fire protection is not required where every part of the roof construction is 20 ft or more above any floor immediately below.
*** 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 and roof panels, which have no connection to the columns, shall be considered secondary members and not a part of the structural frame.

to (i.e. posing risk to, or taking risk from) other buildings, and not equipped with sprinklers. Variations of fire-related risks associated with expected amounts of combustible building contents and expected characteristics of building occupants are addressed through the use and occupancy classifications. There are 11 major categories in the IBC chapter 3 use and occupancy classification:

- Assembly (Groups A-1, A-2, A-3, A-4 and A-5)
- Business (Group B)
- Educational (Group E)
- Factory and Industrial (Groups F-1 and F-2)
- High Hazard (Groups H-1, H-2, H-3, H-4 and H-5))
- Institutional (Groups (I-1, I-2, I-3 and I-4)
- Mercantile (Group M)
- Residential (Groups R-1, R-2, R-3 and R-4)
- Storage (Groups S-1 and S-2)
- Utility and Miscellaneous (Group U)
- Incidental use areas

Table 503 in the IBC specifies the maximum allowable heights and areas for buildings depending on their occupancy classification and type of construction. In other words, for a building of certain occupancy classification, height and area, an appropriate type of construction (and the associated required fire-resistance ratings) needs to be chosen. Larger areas and heights are permitted for non-combustible types of construction with higher fire-resistance requirements, while smaller areas and height are permitted for combustible types of construction.



Further, IBC sections 504 and 506 contain specific provisions for height and area increases, and sections 507 and 508 specify certain exceptions depending on the frontage (open space or public way around the building), sprinkler protection and other factors. Therefore, the determination of an appropriate type of construction sometimes involves an iterative process where several possible combinations of fire safety features (or several combinations of applicable provisions) are considered, and the optimal configuration is selected. IBC Chapter 4 also contains certain occupancy specific requirements and exceptions. For example, the classification of open parking garages and the associated fire resistance requirements are specified in section 406, while some additional requirements for high-rise buildings are specified in section 403.

Individual Protection

IBC article 713.2 requires that trusses "shall be individually protected on all sides for the full length" where the truss supports:

- more than two floors (or more than one floor and one roof), or
- a loadbearing wall, or
- a non-loadbearing wall that is more than two stories high.

The "individual" protection is accomplished through the enclosure of the entire individual truss for its full height and length (usually by gypsum wallboard) or through the enclosure of each truss element by a spay-applied fire resistive material (SFRM), intumescent coating, gypsum board, or other acceptable protection.

This individual protection requirement essentially prohibits the protection of important and "critical" trusses by fire resistive ceiling membranes. However, ceiling protection (shielding more than one truss) can be used for regular truss systems supporting one floor or transfer trusses supporting not more than two floors.

Fire Resistant Designs

The inherently large size of truss assemblies does not allow their adequate fire resistance testing in standard furnaces. However, several conservative approaches have been developed over the years for truss fire protection. One common approach is to protect each truss element to the same level as a column of a similar or smaller section size. Another conservative approach, sometimes used for lighter trusses, is to apply proven fire resistant joist designs to heavier trusses. Both approaches are based on the rationale that larger/heavier truss elements would heat up slower than smaller column sections or lighter joists under similar fire exposures.

IBC Table 719.1 (1) lists many proven fire resistant designs for steel truss elements protected with generic (non-proprietary) materials, such as concrete, plaster or gypsum wallboard. Further, IBC article 720.5.2.3 specifies the method of adjustment of thickness of proprietary SFRM based on the weight-to-heated-perimeter ratio (W/D ratio) of the protected steel section and the number of fire-exposed sides. The thickness of SFRM is determined using IBC Equation 7-13 in the same manner as for columns in accordance with IBC section 720.5.1.3. For truss elements exposed to fire on four sides (vertical, diagonal, and sometimes bottom chord elements) the four-side W/D ratio should be used. Where truss elements directly support floor or roof construction (top chord, and sometimes, bottom chord elements, as in staggered truss systems), the W/D ratio for three-side exposure is used, as for beams and girders. Similar provisions are specified in the ASCE/SFPE 29-99 *Standard Calculation Methods for Structural Fire Protection*.

The largest single source of fire resistant designs with proprietary protection materials (SFRM, intumescent coatings, proprietary types of gypsum wallboard, etc) is the Underwriters Laboratories (UL) Fire Resistance Directory (**www.ul.com**). It contains a variety of designs for columns (X and Y series), walls (U and V series), floors (D and G series), roofs (P series) and beams (N and S series) – many of these designs are suitable for application to structural steel trusses. For example, UL Design U436 is especially useful for the fire resistant design of staggered trusses protected within a gypsum wallboard envelope. Detailed design examples and elaborate discussion of steel fire protection topics can be found in Steel Design Guide 19, *Fire Resistance of Structural Steel Framing,* and *Facts for Steel Buildings: Fire* published by the American Institute of Steel Construction (**www.aisc.org**).■

Farid Alfawakhiri, Ph.D., P.Eng. is a senior R & D engineer with the American Institute of Steel Construction (AISC). ***Alfawakhiri@aisc.org***

Charles J. Carter, P. E., S. E. is Chief Structural Engineer with the American Institute of Steel Construction (AISC). ***Carter@aisc.org***