Fire Engineering®

## Construction Concerns: Structural Collapse

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All structures of any type of construction are similar in that they can be damaged or destroyed by natural forces like earthquakes, floods, and high winds and by accidental or deliberate acts like fire, explosion, and impact.

Damage to a structure can be localized or severe enough to cause its complete destruction or collapse. The extent of the damage is affected by the strength and fire resistance of the structural members, their location in the structure, and the severity of the force or act. Strength, fire resistance, and damage issues of structural members include the following:

- In Type V (wood-frame) buildings, all structural members are combustible. Those of manufactured and composite materials like I-joists and trusses fail more quickly than sawn lumber. Void spaces contribute to fire spread. If an automatic fire sprinkler system is present, it probably protects only occupied spaces.
- In Type IV (heavy timber) buildings, columns, beams, floors, and roofs are combustible; and although they may be more difficult to ignite than dimensional lumber, they are a large fuel load. Load-bearing walls are of masonry that can collapse because of redistributed and eccentric loads as the combustible members burn away or collapse. Functioning automatic fire sprinkler systems have provided good protection for buildings of this type for more than a century.
- In Type III (ordinary; brick-and-joist) buildings, beams, floors, and roofs are combustible. Load-bearing walls are of masonry that can collapse as the combustible members burn away or collapse. Void spaces contribute to fire spread. Functioning automatic fire sprinkler systems provide good protection for buildings of this type.
- In Type II (noncombustible) buildings, the structural members are not combustible. However, they have little mass compared to Type IV or Type I and can be quickly weakened by the heat of a building contents fire. Activation of a fire sprinkler system can confine a contents fire and delay structural collapse.
- In Type I (fire-resistive) buildings, the structural members themselves are resistant to fire or have been made so by encasing them in fire-resistive materials. A contents fire that is hot enough and unconfined by an automatic fire sprinkler system can damage the structural system and cause its collapse.

In addition to failure of structural members, the forces and acts can cause redistribution of building loads and can cause loads that are normally axial (carried straight down through the center of the wall or column) to become eccentric (carried down the side of the wall or column) or torsional (twisting the wall or column). These shifts can overload structural members, can cause the failure of the connections, and can cause local or global structural collapse.


Photo 1 shows part of a school building under construction. The failure of primary structural members or of the connections between them can cause the collapse of the building or a part of it. Primary structural members are those without which the structure will not stand. They include load-bearing walls (photo 1 numbers 1, 1), columns (photo 1 number 3), and girders (photo 1 number 2, including ridge-boards and the trimmer/header assemblies that support stairways).

The failure of secondary structural members or of the connections between them can cause localized structural collapse. Secondary structural members are supported by primary structural members and include roof and floor joists (photo 1 number 4), other types of beams and trusses, floors, partition walls, and roofs.

We must remember that most buildings are “systems” in which each structural component acts with other components and serves more than one function in the completed building. Photo 2 shows a factory building under construction. The primary structural members that are visible include load-bearing walls (precast insulated concrete wall panels), steel columns, and girder trusses. Secondary structural members include the bar joists that will support the roof, the steel bracing that will be installed across the bottom chords of the bar joists, and the corrugated steel roof deck that will be welded or screwed to the top of the bar joists. In these systems

- The load-bearing walls and columns support and brace the structural steel and the roof.
- The girder trusses brace the load-bearing walls and support the roof joists and deck.
- The roof joists (bar joists) brace the load-bearing walls and the girder trusses and support the roof deck and roof.
- The roof deck supports the roof membrane and provides lateral and diagonal bracing to the structural steel to the load-bearing walls and to the building as a whole.

The diagonal braces that are visible between the ground and the wall panels in photo 2 provide temporary support for the walls. They will be removed only after all of the structural steel is welded or bolted in place and most of the corrugated steel roof deck has been attached.

During the ongoing size-up of the building involved in an incident, we must include an on-going structural evaluation:

1. Are the effects of the incident confined to one room or compartment?
2. Are the effects of the incident confined to a single floor?
3. Has the incident compromised primary structural members, with a danger of total collapse?
4. Has the incident compromised secondary structural members, with a danger of local collapse?
5. If number 3 or 4 is true, have axial loads shifted and become eccentric or torsional?
6. Are other loads present that were not part of the building design?
7. If any of numbers 3 through 6 is true, is the structure still stable enough for interior operations, including search and rescue?
8. If number 7 is true, how long will it remain stable enough for interior operations?
9. If numbers 7 or 8 is false, how can we stabilize the structure so that we can perform search and rescue and other interior operations?

For more detailed discussion of these ideas, review


- *Brannigan's Building Construction for the Fire Service,* 4th edition, Brannigan and Corbett. NFPA and Jones & Bartlett, 2008.
- *Building Construction Related to the Fire Service,* 3rd edition. IFSTA and Fire Protection Publications, 2010.
- *Collapse of Burning Buildings,* Vincent Dunn. Fire Engineering Books and Videos, 1988.
- *Safety and Survival on the Fireground,* Vincent Dunn. Fire Engineering Books and Videos, 1992.
- "Lightweight Steel Construction," Gregory Havel. *Fire Engineering* (print magazine) November 2005.
- "Precast Concrete Wall Panels." Gregory Havel. *Fire Engineering* (print magazine) December 2006.



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