“Knowing Your Buildings with FEWLOADPATHS+3-U’s”

It has been nearly a decade since the unspeakable loss of lives at the World Trade Center due to structural collapse. Clearly we will never take out all the risk of structural firefighting. The fire service can expect smaller, more localized failures to continue during rescue and fire attack that will result in near misses, line of duty injuries, and deaths. However, while it is difficult to determine hazardous features and conditions at night and in smoke, competent firefighters and officers can get out and look at these buildings that exist here and now in our first due areas before the fire occurs. In the skill and art of structural firefighting, accurate observation comes first. The professional firefighter depends upon knowledge and experience, rather than luck, for successful incident conclusion. Building construction knowledge begins with the fact that all buildings carry and transmit loads (weights or forces) to the ground through load paths. Recall that load transfer redistributes loads and forces to various supports which increases load stress. Failure (collapse) occurs when the load capacity is exceeded and structural support(s) can no longer carry the load for which it was designed.

The acronym “FEWLOADPATHS+3U’s” describes several of the more typical hazardous features and conditions that create “bad building behaviors” at structure fires:

- **F** Facades and False mansards
- **E** Engineered wood components and Extension
- **W** Warping and Wracking
- **L** Level (Out of Level)
- **O** Out of plumb and Overloaded
- **A** Alterations and renovations
- **D** Deformation, Deflection, and Deficiencies in construction
- **P** Parapets, Penetrations, and Poor condition
- **A** Active bulging, buckling, bending, twisting or sagging
- **T** Trusses
- **H** Hidden voids
- **S** Spaces concealed
- **+3- U’s:** Unprotected, Undivided or Unreinforced masonry (URM)
Facades or false fronts are the non-structural coverings on the face of a building.

Brick, stone, and concrete are typically placed on structural frames that may be dislodged by hose streams/master streams and fail.

Facades, cornices, canopies and overhangs have failed and injured firefighters; often later during fireground operations. Identify these hazardous features, communicate them, establish collapse zones and observe for failure clues like bending, bowing, sagging or pulling away from the wall.

False mansards are a roof-like structure typically attached with light-weight fasteners (nails, gusset plates) to the face of buildings for better appearance. They are often used to face strip malls and fast-food restaurants.

False mansards create horizontal concealed void spaces that allow heat, smoke and fire to travel through and may fail. Consider penetrating nozzles and working off aerial and/or ground ladders to access those spaces.

Engineered wood components refer to prefabricated light weight wood components used for floor and roof support systems like I-joists and parallel chord trusses. Other engineered wood products utilizing laminated veneer lumber are also used for beams (headers), columns, studs, and rim boards.
I-joists, commonly referred to as wood I-beams or TJIs (trade name), are used for floor and roof joists. While able to support greater loads under non-fire conditions, I-joists do not have the mass of solid-sawn lumber. Top and bottom flanges are joined by a veneered material for the web. Proper knock-out holes exist for utilities and are located in the middle third of the web. I-joists are easily weakened by improper hole size and location, notching and by damage to the bottom chord. It is important to note that line of duty injuries and deaths have occurred in roof and floor failures of both lightweight wood I-joists as well as solid sawn lumber. Be cautious if fire has reached the bays of floor or roof support systems. Maintain time and situational awareness in all combustible framed structures.

Parallel chord wood trusses are comprised of chords, webs, and connector plates and are designed to work together. There are several different kinds of parallel chord wood trusses based on the arrangement of its webs. In short, the top chord acts in compression, bottom chord in tension and the web members control the shear and will be either in compression or tension. Connector plates are typically 16 – 20 gauge toothed hot galvanized steel which is hydraulically embedded in the wood of the truss. In residential construction a floor truss most often bears on the underside of its bottom chord. The most common spacing for residential construction is 24 inch and typical truss depths are 14 inch to 16 inch.
These are increasingly used in place of solid sawn lumber as they have the ability to span greater distances, are lighter, more dimensionally stable and able to be installed quickly. Expect engineered wood components in most new construction as well as in renovations and alterations of older buildings. Don’t be surprised to find I-joists in balloon-framed Victorians when a new foundation or floor system is being installed. Unprotected engineered wood components have been noted to fail earlier than dimensional lumber under actual fire conditions in the as-built structure. Identification of buildings with lightweight engineered wood components may be difficult at fire scene which is why prefire analysis and building walkthrough and documentation is essential. The fire service can anticipate earlier failure of combustible, prefabricated, unprotected lightweight engineered beams like parallel chord trusses and I-joists. Extension refers to the progression of fire and the products of combustion into uninvolved areas. Professional firefighters anticipate fire extension into combustible concealed spaces and voids, particularly into large, undivided attic spaces common in large structures like apartment complexes.

Warping refers to a variation from straightness often relating to lumber. A warped horizontal structural element like a wood or steel beam indicates a change in load path and subsequent load transfer which may result in significant stress increases in certain supports. Wracking is when a component, such as a wall, is forced out of plumb. Altered load paths and improper load transfers may result in failure.
**Level** describes an even height, such as in a floor or roof ridge. Give a look at the roof ridge’s levelness during size-up and before vertical ventilation. A sagging roof section will not support the weight of top side firefighters. Ladder and vent away from damaged areas; roofs are designed to carry lighter loads than floors.

*Un-levelness in a normally level floor or roof is not desirable and may indicate an improper load transfer.*

**Out of plumb** means not truly vertical.
A wood framed wall that leans slightly will be adjusted during construction, but under fire conditions, is a serious concern and collapse zones need to be established. **Overloading** is when the load-carrying capability of a structural element is exceeded.

This creates additional internal stresses which may result in failure (a collapse). *Remember, loads are weights or forces that a structure is designed to resist but may be exceed at structure fires by additional live loads (like water and firefighters in a concentrated area) and by fire damage to bearing structural elements like beams and columns.*

**Alterations** are any change, addition, or modification in construction or occupancy. **Renovation** refers to the repairing or remodeling of a building. Both may create challenges to firefighting forces if done improperly.
Altering bearing elements like internal walls without re-engineering the load transfer is an accident waiting to happen. Firefighters need to be aware of buildings under renovation, particularly if work is being done by non-professionals.

Deformation is an alteration in shape or form caused by stress. When a load is applied to a beam, the shape bends. In compression the deformation takes the form of shortening, whereas in tension the deformation takes the form of elongation. Deflection is the movement of a structural element under a load which increases with load and span. Codes and engineering charts specify allowed values for structural members. Visual deflection calls for a collapse zone designation; no firefighter in, on or around the deflected bearing area.

Deficiencies in construction, rather than the lack of fire endurance of a material, are responsible for many structural failures (NFPA 16th edition). Unprotected structural elements, particularly steel beams and columns will deform when heated and cause undersigned (and undesirable) load transfer.

Parapets are low walls that rise above the roofline. Observant firefighters will note these on many older Type III unreinforced masonry buildings (URMs). Even when retrofitted, they may not withstand lateral loads very well which may cause them to flex and fail (collapse). Heated steel lintels and hose streams/master streams have caused parapet failures. See Vince Dunn’s book, “Collapse of Burning Buildings” for important details.
**Penetrations** are openings through fire-resistance-rated assemblies.

Fire, heat and smoke may extend through these openings which will cause extension into uninvolved parts of buildings. Penetrations occur by improper sealing of openings and by trade persons making alterations to walls, floors and attic spaces.  *Remember, the as-built structure is our working environment; fire and the products of combustion do not read blueprints or construction documents but follow the laws of heat transfer, particularly convection.*

**Active bulging, buckling, bending, twisting, sagging** or any moving building part (bearing or non-bearing) are not desirable characteristics, particularly during fire attack.
The superstructure is the portion of the building that distributes or carries the load. Superstructures are divided as either wall bearing or frame bearing and utilize horizontal, vertical and lateral load-carrying systems. Fire damage to combustible structural members and heat exposure to unprotected steel frames equals a loss of the load-carrying capability which invariably results in load transfer and possible failure. **Bulging, buckling, bending, twisting and sagging are visual clues to changes in load paths.** Immediate warning announcements need to be made and collapse zone designations established.

A **truss** is a structural configuration that converts the bending moments and sheer forces produced by loading into compressive and tensile forces. These forces are directed through the individual truss members and transferred to the walls. Trusses can span greater distances with less material and weight than solid beams. These long-span structural elements are standard features in most all large, newer buildings and frequently used in supermarkets, shops, big box stores, high rises and in a variety of occupancies.
Trusses are constructed out of wood, steel, concrete and combinations of materials. Typical shapes include flat (parallel chord wood trusses, steel bar joists, Warren), arched (bowstring, hip carrier), and peaked (scissors, Pratt, How, Fink). They may be protected by sprinkler systems or gypsum board or unprotected when certain heights above the floor are reached. As the combination of a truss’s plates, webs and chords are designed to work together; damage to one component may cause the entire truss to fail. Trusses have failed due to fire damage, overloading and inadvertent fire ground actions. If fire is observed to impinge upon any truss member, the entire truss may fail, causing load transfers and secondary wall collapse. Dunn reminds us: “Don’t trust the truss.”

**Hidden Voids** are empty spaces between members of a structure that remain unseen without removing coverings.

Voids have contributed to the spread of many large-loss fires particularly in Type III and Type V buildings that have inter-connected combustible voids. Balloon framing with combustible wood joists, floors and rafters are notorious for fire spread in these void areas. Brannigan says to “visualize the voids” in order to get ahead of fire extension.
**Spaces Concealed** (or concealed spaces) are areas that are covered and yet allow for fire spread to occur undetected.

Concealed spaces include roof buildovers and multiple dropped ceilings. All concealed spaces where fire is suspected need to be opened up. While easily said, many combustible concealed spaces are difficult to access due to height or strong materials. *Whenever possible, open up these spaces from safer locations like door openings and sides of rooms and off of ladders. Consider using penetrating or piercing nozzles to access concealed spaces.* Again, Brannigan advises us to “undress the building.”

**Unprotected** means without fire resistance. It refers to the lack of fire protective coverings which expose the wood or steel to heat and/or flame. Light weight wood, both dimensional lumber and lightweight engineered wood components, are combustible and will fail under fire conditions. These may be impossible to detect during fire ground activities. Pay attention to tell-tale signs when opening up floors, ceilings and walls. Poor quality construction may indicate shoddy work and improper load carrying ability of connectors and/or structural members.
Unprotected steel during fires, particularly as used in composite construction as bearing-elements within wood, masonry or concrete wall systems, will absorb heat and push out walls by expanding, twisting or buckling. *In this case, cool the steel and establish localized collapse zones.* **Undivided** refers to space typically in attic, cockloft and false mansard areas that allow fire to travel throughout unobstructed. Older apartment buildings may have large, non-compartmentalized, undivided attic spaces. While current building codes limit the area of these spaces, penetrations and alterations to these spaces allow fire and the products of combustion to spread. **Unreinforced masonry (URM)** is brick, block or stone that are not reinforced with steel. Many of these older buildings have not been well-maintained and may be in poor condition. Red flags and hazard buzzers should be going on inside your head when URM roofs and floors are damaged by fire.
Many URMs are older Type III buildings with interior wood framing, and larger URMs may utilize unprotected steel and timber with steel or wood/steel combination trusses for the roof support system. These are particularly hazardous building features and need to be communicated to all fire ground companies. Fire in the truss loft or truss void may cause truss failure, which can cause the secondary, unreinforced masonry wall collapse. Unprotected steel columns, beams and lintels when heated by fire may cause roof and then wall failure. Be extra alert and vigilant at these fires.

“…wise men learn from the experience of others” (Otto von Bismarck)

We each must be responsible for safety and not be unnecessarily exposed to identifiable hazardous building features and conditions at non-rescue firefight. We each have the ability to know our buildings by getting out and looking at those hazardous buildings and features that exist here and now in our first due areas before the fire occurs.

- Life safety, which absolutely includes firefighting forces, is always our first strategic priority
- We only risk a lot to save a lot
- Hazard avoidance and risk reduction are the hallmarks of smart firefighting
- Fire ground risks may not be easily managed but they can be identified
- Be situationally aware in order to reduce mental errors
- Communicate observable hazards and changes to the building and ensure companies operating in, on or around are hazard aware
- Control unnecessary firefighter exposure to hazardous features
- When operating in or around hazardous building features or conditions, limit the time and exposure to those hazards
- Part of our job is to avoid falling objects and to avoid becoming falling objects ourselves due to changes in load paths
• Firefighting is not complicated; separate energy (heat), fuel (fire load) or oxygen and match the fire’s size and intensity with water as early as possible to minimize its growth and ultimately put it out
• Firefighting is always a serious affair; don’t be a firefighter rarely impressed by anything except by himself/herself
• Balance deliberate and intuitive thinking at structure fires and use each in the appropriate circumstance
• Right viewing, right thinking, right acting
• The professional firefighter is a problem solver; work the problem
• The professional firefighter is effective by doing the right things
• The professional firefighter is efficient by doing things correctly
• The professional firefighter is safe and able to do it again and again
• Do more building walk-throughs and district familiarization
• Become more building literate through diligent study and on-going company training
• Get out of the station and look at hazardous building features and determine ladder spotting and hose lengths
• Train for firefighter rescue and survival
• Re-double training for identification of building hazards with appropriate safety awareness actions
• Do regular “Tailboard Talks for Safety” at buildings that pose greater risks and challenges during fireground operations
• Seek out and talk with experienced and knowledgeable firefighters who know your area’s specific construction hazards and fire history
• Review successful structure fire outcomes and talk with fireground crews on what went right
• Read and discuss after action reports, critiques, post-fire analysis
• Pay attention to new construction, remodeling and building alterations and features when returning from calls and other duties
• Drill and train regularly on hazardous building features and conditions by doing simulations and realistic mock scenarios of specific fire conditions in specific buildings
• Ensure your department has a way to communicate hazardous features and conditions at the fire scene
• Ensure reports on conditions are updated by companies at different times and locations
• Ensure your department has appropriate offensive fire attack criteria and “trigger points” for defensive operations
• Discuss your department’s expectations for fire control at vacant or derelict buildings
• Discuss your department’s expectations for fire control appropriate to the risk hazards of your area and staffing levels for alarm responses
• Ensure your department’s standard operating procedures match resource availability and capability for various building types and/or occupancy
• Discuss your department’s fireground differential diagnosis (paramedic-speak) to quickly arrive at a starting point. These may include a good building description, the fire and life profiles, time monitoring, proper fire flow for the fuel load and a re-examining of assumptions when there is no change in the fire as a result of fire attack and ventilation.
• Utilize knowledgeable structural engineers that work with local FEMA Task Forces as well as building and demolition contractors, house movers and fire technology construction instructors in your area
• Create photo inventories of those hazardous buildings that you have surveyed for your area (and share them with the B shift)
• Create a “hazard file” for dispatch to notify responding units of those specific building addresses that pose a significant risk during fires
• Improve your department’s prefire planning system. Utilize NFPA 1620: Recommended Practice for Pre-Incident Planning and NFPA 170: Fire Safety Symbols. While prefire analysis and plans are important,
recall that the planning and thinking process is critical for safety and performance improvement on the fireground.

- “Proper planning prevents poor performance”
- Lead a company, station, battalion, or department drill on a building construction related topic. Have each firefighter or company bring a projectable digital example of a particularly hazardous life, fire or building challenge.
- Research:
  - Firefighter Fatality Assessment and Control Evaluation (NIOSH FACE): [http://www.cdc.gov/niosh/face/](http://www.cdc.gov/niosh/face/)
  - FACE publications: [http://www.cdc.gov/niosh/fire/othpubs.html](http://www.cdc.gov/niosh/fire/othpubs.html)
  - “Fire Research You Can Use”: [www.fire.gov](http://www.fire.gov)
  - NIST Building and Fire Research Lab Structural collapse fire tests: [www.fire.gov/collapse/index.htm](http://www.fire.gov/collapse/index.htm)
  - American Wood Council: [www.woodaware.info](http://www.woodaware.info)

We cannot predict in which buildings fires will occur. We cannot predict in which buildings failure will occur. But we can remember FEWOODPATHS+3U’s as a way to be more observant and to communicate identifiable building hazards in order to look after each other while saving lives and property. We are grateful to the Brannigans, Dunns, Mittendorfs, Smiths and others who have helped to safely improve our fireground actions by better knowing our buildings. They have contributed greatly to reducing near misses, line of duty injuries and deaths. Lastly, may we never forget those taken at ground zero. Our fellow firefighters’ “…acts deserve acts, not words, in their honor…”(Pericles, 450 BC).

Stay sharp, stay strong, stay safe.

BIOGRAPHY:

CA Craig Schwinge (SJFD ret) is the author of “Knowing Your Buildings: A Firefighter’s Reference Guide” (Delmar/Cengage, 2010). He is an adjunct fire technology instructor at Cabrillo College (Aptos, CA) and general building contractor. Comments and photos of specific building features are welcome at: crschwin@cabrillo.edu.