Street Smart Modern Construction Considerations for Firefighters

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As all firefighters know, structural fire fighting carries a risk. Therefore firefighters need to conduct a risk-benefit analysis before deciding on tactics to manage a given fire situation. The first step in risk-benefit analysis is to determine if search and rescue is appropriate. Initial fire size-up should be used to estimate how long the fire has been burning and then evaluate the potential for survivors within the building.

According to research reported by the National Institute of Standards and Technology (NIST) Building and Fire Research Laboratory, in 2004, smoke alarms consistently provide people enough time to escape most residential fires. Their research has concluded that occupants generally have an approximate three-minute escape window after the smoke alarms activate before limits of tenability are reached. A similar test conducted in 1970, found that the escape window was 17 minutes at that time. According to NIST, fires today burn faster and kill quicker because the contents of today's homes, such as furnishings, are different than 30 years ago and can burn faster and more intensely[1].

If the potential for survivors is high, then it would be appropriate to consider search and rescue operations. If the potential for survivors is non-existent then the fire situation should be viewed as property protection. A risk-benefit analysis should indicate that firefighters should not risk their lives for protecting property. Some building fires should perhaps be allowed to burn longer in relative safety rather than risk personnel for offensive interior operations.

The following information should be useful if a risk-benefit analysis warrants entering a burning building for search and rescue or offensive interior attack for property protection.

Sound decision making at fires requires knowledge of fire behavior and building construction, as well as an understanding of how these two interact to pose a threat to firefighters. Over the years, experience has led to the development of successful tactical practices, procedures, and rule of thumb guidelines for "safe" working times[2] during offensive interior operations. This experience was based primarily on fires in older buildings of ordinary conventional construction materials (i.e. full-dimension sawn lumber) and techniques. The traditional approach has been that, barring total involvement on arrival, in older structures of that type we generally have time to vent the roof and windows, enter and search the building, and extinguish the fire prior to the imminent collapse of the structure. As NIST had reported in 2004[1], the fire characteristics of building contents have changed substantially during the past 30 years, primarily, to meet the changing needs of building users and the availability of newer materials.

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[1] http://smokealarm.nist.gov/

[2] The concept of a "safe" working time should underlie all decisions on interior offensive operations. In severe fires, however, there is no way for anyone to predict how much time remains until structural collapse, regardless of construction type.

Building construction methods and products have also changed to meet the changing needs of building owners and occupants.   As such, tactical rules developed with previous fire experiences are not necessarily applicable to newer buildings or older buildings with today's contents.

The Changes in Modern Building Construction

To address consumer demand for larger open spaces and environmentally-friendly construction products, the building industry has gradually moved away from resource inefficient conventional construction methods and materials to construction techniques and components that use lumber more efficiently. This has resulted in construction products having greater strength but less mass, and assemblies with less structural support and with more open areas within structural members. Modern products have been engineered to allow much longer spans without intermediary supports. Many firefighters, perhaps correctly, feel it is necessary to rethink tactical procedures and guidelines for fighting fires in these newer structures with newer contents. Resource efficient modern products, while environmentally-friendly, have less resistance to fire than the traditional sawn lumber products.

Despite a reduction in fire resistance, and building contents that yield more fire toxic gases, there has been a steady decline in occupant fire deaths and injuries. Annual occupant fire deaths reduced from 4585 to 3675 between 1995 and 2005 reflecting a 20% decline. It is apparent that improved fire warning systems and occupant education on the need for faster fire evacuation have more than made up for the otherwise adversarial conditions. In contrast, however, firefighter deaths from structural collapse have remained stagnant, at about 5-8 deaths per year, during this10-year period. Statistics show that 92% of firefighter deaths due to structural collapse may have been avoided by a risk-benefit analysis.

Many in the fire service are of the opinion that the increase in use of products designed to use lumber more efficiently from an environmentally-friendly standpoint is not necessarily safer from a fire fighting standpoint. This is coupled with the facts that walls are no longer lath and plaster, floors are not as thick as they used to be (oak floor with sleepers versus vinyl products on a single thickness sheathing) and the contents of buildings have changed. These changes and perceptions invite a rethinking of tactical procedures and guidelines for fighting fires in these "modern structures." Using a thoughtful approach to fire fighting in modern construction may reduce the chance of being killed or injured, regardless of materials used.

A combination of modern construction methods and materials with previously used methods may be found in the same structure. Regardless of the methods used, firefighters must be aware of the conditions effecting the structural portions and the influence it may have on their safety.

Part of the concern with modern construction stems from the perception that the structural fire resistance of conventional wood-frame construction provides a much greater degree of safe working time than for modern construction.   As a practical matter, no two fires are the same and a structure's fire endurance and mode of failure under real fire conditions is unpredictable. Time can quickly be forgotten on the fireground and firefighters may not be able to determine if this time has already been exceeded when they arrive. This necessitates a rethinking of tactical procedures and guidelines for fighting fires in these newer structures or newer contents. Using the same tactical thinking, procedures, and timelines that were commonly used in years past are not the best applicable for modern construction or modern contents.

Heat and smoke still rise until something stops them, then they move horizontally until something stops them, and then they bank downward, filling the entire area. Though basic fire behavior may not have changed greatly, fires themselves have changed. The increased BTU production of today's fires, due to the large amount of petroleum based plastic and other building contents, coupled with tighter and better insulated buildings, often means fires burn hotter and reach flashover much quicker than in the past. The denser smoke can obscure flame and impending collapse conditions, and this coupled with the over-reliance on insulating hoods and protective clothing, can mask heat conditions and cause firefighters to enter areas in which they should not be operating.

It is still true that the smaller the mass of the fuel, and the more surface area exposed to heat, the faster the fuel will ignite, burn, and fail. Also, the more numerous the connectors between structural components, the more likely a sudden failure under fire conditions could occur. Third, the less compartmentalized a fire is the faster it will spread, both vertically and horizontally. The actual type of building construction, due to various factors including remodeling, is not always readily apparent.

From a fire behavior tactical standpoint, we must be aware of the type of building construction (wood, reinforced concrete, steel), the applied weight to the structure (building contents, snow, ice, etc), and how the fire is moving. Also keep in mind that as it is growing, and once it becomes more than a minor contents-fire, it may be attacking, weakening and/or consuming the structure itself.

Today's construction, both residential and commercial, makes frequent use of trusses to support roofs and floors. They are considered engineered products and may be made of wood, steel, or even a combination of the two. The top and bottom members of a truss are called chords. They are connected together by webs to form a series of triangular shapes that provide strength. The three most common types of trusses are the parallel-chord, bowstring, and peaked designs. The other common type of modern support system is the wooden I-beam or I-joists. These likewise have top and bottom chords, but typically use approximately 3/8" wood sheathing in the web for support.

Modern construction components, due to their resource efficient nature and design have less mass. They also have more surface area (relative to mass) exposed to fire and thus may be more susceptible to sudden failure than full dimension conventional sawn lumber components. They use smaller dimension lumber than residences built many years ago, and they use metal connectors instead of common nailing methods. In addition, the open arrangement of these components provides reduced compartmentalization, and allows rapid fire spread throughout the roof and floor systems. In most cases building codes require draft or fire stopping, but history has proven that these are not always present or properly installed. It is important that all construction methods are properly designed, installed and maintained. In order for this to occur there needs to be proper training of building inspectors and proper enforcement.

Failure in modern construction can involve a large area rather than a localized spot, regardless of whether the supports are close together or twenty or more feet apart. In addition, most engineered systems are interdependent, so the failure of one web component has the potential to cause additional stresses on adjoining components and the entire system. This may or may not happen, depending on the circumstance, but you must anticipate it.

Don't Risk your Life to Save Property

Rapid fire spread and early structural collapse are two primary hazards to firefighters during fires in all types of construction, particularly in modern construction methods or modern contents. Even if structural components are protected with drywall, poke-throughs are common and the drywall or a suspended ceiling may be suspended below the structural members allowing a large void space for fire travel. There may be no protection against a fire which starts within this protected void area. As such, a floor or roof system can collapse without warning. Fire codes often require sprinklers within concealed spaces, especially in commercial structures, but not always. The point is that the firefighter should be aware of these variables within all types of construction, not just modern engineered wood construction.

Metal gusset plates and other metal connectors are often used in trusses to connect chords and webs, as well as to make splices. Gusset plates are attached by a series of teeth which penetrate the wood approximately 5/16" – 3/8" inch. Fire performance of the metal plate would be influenced by the wood moisture content, applied load to the joint, depth of teeth penetration, and the time of fire exposure. After one plate fails, the remaining gusset plates can also be influenced by the changes in tensional forces causing additional compromise to the truss. Remember, that once any member of a truss fails, the entire truss becomes suspect.

Due to the open spaces, numerous trusses can be attacked by fire simultaneously. Thus, you cannot count on the adjacent truss picking up the loads formerly carried by its weakened neighbor, such as might happen with systems without fire damage.

Today you should also at least anticipate fast large area fires running horizontally rather than being channelized in walls, floors and ceilings, as is common to balloon frame buildings, which also require different tactics. You may now be working over or under a greater volume and area of fire than expected. The fire may be readily destroying the structural supports for a sizable area of the building. You have little time to safely hunt for and extinguish these fires.

Rapid fire spread alone would not necessarily be an insurmountable problem for adequate sized hose lines. However, it becomes a very serious consideration when you recognize its relationship to quick structural collapse. In addition to the wood being consumed there are other factors that contribute to collapse potential.

Large dimension trusses have been used for hundreds if not thousands of years. Buildings, such as churches, bowling alleys, and car dealerships commonly have large span roofs with very high ceilings. Typically these have been either peaked or bowstring trusses by design, and were constructed of 4 inch or larger timbers and/or steel. Frequently they incorporate steel bolts, plates, and tie rods for structural integrity. Fires can give the appearance of tenable conditions at floor level but the fire may be actively attacking the structural areas. These trusses have been known to be loaded improperly on the bottom chords, such as by the storage of car parts. In addition, they may have been damaged over the years due to snow loads or accidents within the building and have never had repairs. Such considerations are necessary when conducting a risk analysis for a fire incident at these buildings.

Bowstring trusses, for example have been involved in numerous building collapses, several of which have resulted in multiple firefighter fatalities. These have occurred in two basic ways. One involves firefighters falling through the roof into the fire when a large section of roof suddenly fails due either to burn through of the decking or failure of supports. For instance, if the trusses are spaced every 20 feet, and only one truss lets go, it results in a 40 foot unsupported span. The failure of one truss can cause it to change the loading forces on the adjoining trusses. This could instantly result in a lost area 80 feet long and the full width of the building.

A second way these large trusses, and other buildings with large areas have caused injuries and deaths, is by burying people under the debris from collapsing roofs and walls. If a truss or steel I-beam expands, twists, or falls, any of the four walls are subject to collapse. However, a large area wall collapse in a bowstring truss building is most likely to involve the front and rear walls. This is because as the truss falls it is apt to exert pressure down and outward on the rafters bracing at the ends of the building, thus pushing the end walls. Peaked trusses are more apt to buckle side walls. However, remember there is no “always” in collapses. Keep your distance, at least one and one-half times the height of the building, and be aware of potential secondary collapses. Remember, more firefighters are killed outside buildings by collapses than inside. Also, position your rigs outside the collapse zone, preferably at the corners.

The problem with long spans and engineered components is not limited to wood products. A piece of steel 100 feet long can expand almost a foot when heated to approximately 1,000 degrees Fahrenheit. Steel trusses, commonly referred to as bar-joists, also expand when heated. Depending on their loading, they can twist and dump their load, or they might simply expand and push walls outward. In either case, collapse may result. Severe fires generate temperatures well in excess of 1,000 degrees F. A number of years ago there was concern about the effect of putting water on hot steel beams, columns, and joists. However, if you do not cool the steel it will expand, twist, or sag, and fail, so if possible cool it quickly from a distance.

It is not enough for officers and firefighters to merely know the difference between types of building construction. You must also be aware of standard construction practices for various types of construction, including wood, steel and concrete. Through pre-fire planning you must be aware of the actual buildings in your response area, and learn to look for and recognize indicators of different types of construction, including changes made during remodeling. Then you must apply tactics that are appropriate for the building and the fire conditions to which you have responded, and the situation you encounter. You don’t fight every fire the same way.

Thorough pre-fire planning, and communication of essential information to all fire personnel is the first step. Get into your buildings, and take photographs before the siding and drywall are installed, if possible. Note voids and concealed spaces, as well as the types of construction materials, methods, and quality of workmanship used. Take pictures of the rough construction for future firefighters to review.

If the structure is already enclosed, look for telltale indicators such as the age of the building. Unsupported spans of more than 25 feet almost always mean an engineered assembly of some type was used. Often you can see the hump-back roof of the bowstring truss, but sometimes it is hidden behind a parapet wall. A front wall that is stair-stepped rather than rectangular at the top corners often conceals a bowstring truss roof. Are there cracks, tie rods, or other signs of weakening in masonry walls? Is the building partially supported by adjoining structures, or is it freestanding? Any previous fires here?

In addition to what you know from pre-planning, a good size-up while responding and on arrival is essential. The time of day or night and your response time may give some indication of how long the fire has likely been burning. Where in the building was the fire reported as being? We seldom know everything about the building and the fire, but our decisions should be thoughtful, cautious, and put the odds on our side. They should involve a continuing analysis of changing conditions. Evaluating your tactical mode (defensive versus offensive) every 10 minutes is a good way to reduce the chance of a firefighter death or serious injury.

Next, analyze the fire conditions in relation to the type of construction. Key size-up indicators are the volume and action of fire and smoke, and their location. If you quickly determine it is only a contents fire that has not extended into the structural components, standard "vent and enter" tactics are generally appropriate. However, do not forget to promptly open ceilings and concealed spaces to check for hidden fire as you move into and through the building, and also during overhaul. Observe any indications of weakening, and advise fellow firefighters and officers. Roof venting may draw fire up through the truss area, so be ready to quickly control it before it becomes a problem. This does not mean that you should not vent the roof if necessary. Just be observant and on guard.

The other extreme would be if you obviously have heavy smoke and fire under the floor or in the attic area on arrival. If this is the case, stay out of and off of the building for fire fighting purposes. Most of these roofs will be equipped with roof vents that go right into the attic area. Take a look at what is coming out of those vents. A heavy push of smoke and heat or flame out these vents indicates a serious situation inside. Even search and rescue becomes a judgment call, since we do not want to compound the problem by making firefighters victims, too. Anticipate structural collapse, and set up defensive operations. A risk analysis would suggest that this is not a situation in which to be overly aggressive, nor to take chances.

Do not fool yourself into underestimating the situation, and thinking you can handle it just because all the fire is above you in the attic or loft, and there is little or no smoke on the floor below. Even if the roof has vented, it does not mean you are safe. Actually, it is another indicator that the fire has been burning intensely in the truss area for sometime. It is a danger sign. If heavy streams do not immediately knock down the fire, the situation will continue to deteriorate. Remember the Hackensack, New Jersey Ford dealership truss collapse. When the supports eventually fail, the building is coming down.

A more difficult tactical situation can occur when the location and extent of the fire are less certain or unknown. In those instances you must, if safely possible, get into the building to quickly make an interior size-up of conditions. If either a contents fire or a serious fire in the attic or basement area is found, follow the procedures suggested previously.

In these less certain situations, the incident Commander might receive conflicting reconnaissance information from inside and outside the structure. He should believe the most serious conditions reported. Especially in commercial buildings with considerable height to the roof, it is quite possible for interior crews to report little or no heat and fire. This is because, though heat is building up high, it has not yet banked or radiated downward to the extent it would in a house with eight- foot ceilings. As a rule of thumb, the height of a truss equals 1/8 of its length. That means 12 feet of height for a 100-foot span. Also, the fire may be hidden between the ceiling and the roof. In addition, fire conditions may be masked by dense smoke, and flames overhead may not be visible until just prior to flashover.

Conversely, crews outside may report considerable smoke, heat, and fire in the upper areas of the building and on the roof. They obviously see something that the interior crews do not. The Incident Commander must act according to their observations. At a minimum, information regarding the more serious conditions must be relayed to the interior personnel, and they probably should be evacuated from the building. Defensive operations should be considered.

By venting the roof in smaller fires, if possible, you may be able to localize the fire so that it does not grow to involve the entire attic area, and cause total collapse. If you send a crew to the roof, they should not go onto the roof until interior and exterior conditions have been assessed including the roof sheathing and associated structures. It is much safer to vent roofs from an aerial ladder or basket, rather than by standing directly on the roof. In situations where firefighters are working directly on the roof, multiple ladders should be placed at two or more locations around the building. This provides alternative escape routes, and enables several people to leave the roof at the same time in an emergency.

The roof crew should take the proper tools for the type roof encountered. Normally this will include saws, long pike poles, Halligan bars, and axes. An escape rope is an added safety item. A hose line should not be taken to the roof, unless the roof is covered with a fast burning rubber membrane and a line is needed to protect firefighters should this membrane ignite. Not only is a hose line extra work, but you definitely do not want to become involved in water application through a vent hole. Cut the holes fast, and get off.

There are some unique safety considerations for working on any roof. For example, it is quite likely that as you make your ventilation cuts the roofing material will start to droop and sag down at the edges toward the hole. Especially if there is melted tar from the fire below, the area around the hole will not only start to slope into the hole, but may also become slippery as well. The person using the saw could slide into the hole. Using a second firefighter as a guide to hang onto the one sawing will not only reduce the chance of slipping into the hole, but it will minimize the risk of backing off the edge of the roof or into another hole. When working on buildings with structural supports spaced several feet apart, it is best to work from a basket, not by standing directly on the roof. This minimizes further danger from any sheathing failure.

If you are going to successfully fight any fire, you must have adequate water flow capabilities. Full sprinkler systems are ideal, but they are not common. For residential fires, inch and three-quarter hand lines are the smallest recommended. They provide 180 GPM. Multiple inch and three quarter hand lines may be useful in office and apartment buildings, but recognize that their flow and reach probably will not be adequate for a good fire in the attic. Two and one-half inch lines flowing 250-325 GPM are needed for these fires and for commercial occupancies. Master streams will be necessary for knockdown in some cases, but with a lot of fire careful consideration must be given to any subsequent interior operations. During pre-fire planning, you should calculate the critical flow rates for the entire structure as well as various sections.

As the interior crew advances, the ceiling, floors, and voids should be opened to monitor the conditions above and around you. This includes areas of suspended ceilings so that the fire conditions can be monitored. If you encounter considerable heat, but cannot find and extinguish the fire quickly, get out.

Remember, you have very little time to offensively fight a fire once the structural areas of the building become involved. Do not get trapped into a fifteen or twenty-minute-long search for the fire and subsequent extinguishment. Offensive fire fighting needs to be supported by continuing re-evaluation and size-up of the conditions. Conditions should be quickly changing for the better or consideration should be given to a defensive operation. Ten (10) minutes of a fire impinging on structural elements is a significant exposure, and it may already be too much time to avoid structural collapse.

Do not work directly under or over the burning area. If fire is hidden above a ceiling, use the hose stream or a long pike pole to make a large opening for water application upward into the concealed space for quick extinguishment. Exit the building if this is not possible. In commercial and retail buildings this may be accomplished by taking out a window and pulling ceiling from the sidewalk. Operate a large hoseline into the ceiling area for 45-60 seconds, then shut down, and read the results. If fire pushes back at you, get away from the building and anticipate collapse.

When there is no ceiling, and you can see or know the fire is moving into a large open area with structural supports, position your crew away from any area that is involved in fire. Direct the two and one-half inch hose line up into the area and back and forth to stop the horizontal spread of fire. Then drop the stream down to the base of the fire and kill it. Knockdown should be immediate, or interior operations should be abandoned.

Fire in floors might be better attacked from the room below, as you would an attic fire. In essence you have a cockloft on each floor. Sometimes, after removing siding, an exterior straight stream can be used to sweep the void space of the floor from the outside. If these techniques are not effective, pull out and go defensive.

Defensive Fire Fighting May Save a Life

Firefighters must know the various types of buildings in their response area, and how those buildings typically react when on fire. Pre-fire planning and accurately identifying construction materials and methods can provide a basis on which to base strategy and tactics at any fire. When lacking accurate information about construction and the fire, or when you know you are dealing with a weakened building or modern construction, firefighters and officers must take a conservative approach, and anticipate the worst-case scenario. Time is not on your side. Either get a quick knockdown, or pull your people out.

It is important that firefighters, company officers, and chiefs understand the different types of building construction, fire behavior, and how they interact. Departments should develop SOGs for various types of buildings and situations, and chiefs should make sure their company officers fully understand, before the fire, what tactics they will and will not allow in various buildings, and under what circumstances. Regardless of building type, it is the responsibility of all officers to think about time, control aggressiveness, and keep firefighters out of risky locations and situations where they should not be.

For all types of construction, stay off roofs and floors with significant fires beneath them. Older buildings and modern construction can both collapse without warning. In reality, the endurance time of construction is relative to the conditions found upon arrival and time of burning prior to arrival. Subsequent actions taken should be based on a good risk analysis and continuous re-evaluation of the situation.

<ins>SUMMARY</ins>

As a part of a United States Fire Administration partnership program with the American Forest & Paper Association, a web page and training materials have been made available to the fire service. The authors strongly recommend that you make building construction knowledge as well as the proper knowledge in risk analysis and tactics important in your career, in an effort to save the lives of firefighters. **You are encouraged to become a part of the information exchange between the wood products industry and the fire service. A web page and training materials have been made available at www.woodaware.info. Please email your comments to fire@woodaware.info or use the comment box at the web page.**

Firefighters should also refer to the Illinois Fire Service Institute web page http//:www.fsi.uiuc.edu and the National Fire Academy site for additional information about fire fighting in various types of building construction.

In addition, conduct preplanning of the buildings in your area using standards such as NFPA 1620. **Remember that the information you gather today**

can make a difference in someone's life many years from now. Remember it is all about everyone going home.

For further reading:

All firefighters and officers should be familiar with the following books:

"Building Construction for the Fire Service" by Frank Brannigan

"Collapse of Burning Buildings" and "Safety and Survival on the Fireground" by Vincent Dunn.

These books discuss various types of building construction, old and new, and provide valuable information for fighting fires in them.

Additional resources include:

"Take Full Advantage of Fires Diamond Time" available at:
http://firechief.com/mag/firefighting_full_advantage_fires/index.html

http://www.everyonegoeshome.com

"Nobody in, Everybody out" by Ronny Coleman in Sprinkler Age, 2000.

http://firechief.com/mag/firefighting_full_advantage_fires/index.html

http://www.carbeck.org