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**OCTOBER-NOVEMBER NEWSLETTER- THREE STORY FRAME**

Of the five types of building construction (Fire resistive,non-combustible, ordinary, heavy timber and wood frame) wood-frame construction presents the greatest firefighting danger. In 1998 Two officers of the FDNY died when the second floor of a three-story wood-frame building collapsed. They were thrown into the fire on the first floor. In the 1980s during a two-year period, a chief and a company officer were killed and an officer and nine firefighters seriously injured in four separate collapses of wooden buildings.

To understand how a burning wood-frame residence can collapse and how to extinguish a fire burning within a wood-frame building, a firefighter must know how a wood-frame building is constructed. The four most widely used methods of wood-frame construction over the past two hundred years are braced-frame, balloon frame, and platform frame, and lightweight wood truss construction.

**Braced-Frame Construction**

In the eighteenth and nineteenth centuries, the first large wood-frame buildings constructed along the East Coast, which still stand today, were of braced-frame construction, sometimes called "post-and-girt" construction. This type of wood-frame structure has a braced framework of vertical timbers called "posts," which are positioned at each of the four corners of the building, and horizontal timbers called "girts," which are found at each floor level. These large timbers reinforce the entire two-by-four-inch wood-frame structure and are connected together by mortise-and-tenon joints. (The large timbers and the mortise-and-tenon joints are indicators of braced-frame construction.) The ends of the horizontal timbers are cut down to fit mortise openings which are cut through the vertical timbers.

**Balloon Frame Construction**

As the population moved westward in the nineteenth century, the need for housing increased, and cut and finished large timbers and skilled craftsmen became scarce. A lightweight, quickly assembled wood structure, which needed no large timbers, called "balloon frame construction" replaced the Eastern braced-frame method of constructing wood structures.

To erect a balloon frame structure, four wood exterior walls are constructed flat on the ground. Two-by-four-inch wood studs, extending in one piece for the full height of the wall, form the enclosing walls; the four walls are then lifted upright from the ground and connected like a box at the corners. The advantage of this type of wood construction is speed and the absence of large timbers. The drawback is a vertical void between the wall studs, which extends

from the foundation sill to the attic cap and allows hidden fire and smoke that penetrate the wall space to spread vertically for two or three floors. This unobstructed opening between each stud in the exterior wall, extending from the foundation sill to the attic cap, is an indicator of balloon construction.

**Platform Construction**

The platform construction method builds a structure one level at a time. One complete level of two-by-four-inch wood enclosing walls are raised and nailed together; the floor beams and deck for the next level are placed on top of these walls. The next level of two-by-four-inch wood enclosing walls are constructed on top of the first, and the floor beams and deck for the next level are placed on top of these exterior walls.

From a fire protection standpoint, platform construction is superior to balloon or braced-frame construction, because there are no concealed wall voids which extend for more than one floor.

**Lightweight Wood Truss Construction**

Lightweight wood truss construction is the most common type of wood construction built today. It may replace platform construction, but, from a fire protection point of view, it is inferior compared to platform construction. The sheet metal surface fasteners used to connect the truss members is a defective structural connection from a fire protection point of view. The burning truss floors and roof can collapse within 10 minutes of the arrival of the firefighters. It is not possible to extinguish a fire in the concealed spaces of lightweight wood construction.

**Wood Floor Collapse**

The 1998 collapse in a wood frame building that killed two FDNY fire officers was due to an illegal alteration of a floor system and fire destruction of the second story floor beams. A partition wall supporting the 2nd floor was removed during the alteration.

**Wall Collapse**

The walls of wood buildings collapse more frequently than the wood floors. Wood floor beams may be 2 x 10 inches while the wood walls may only be 2 x 4 inches. However when the walls collapse it causes the floors and roof to also fail.

**Types of Wall Collapse**

There are three ways in which a wood-frame building's wall can collapse during a fire: one wall may fall straight outward at a 90-degree angle, the entire building may lean over and collapse on its side, or one or all four wood enclosing walls may crack apart and fall in an inward outward collapse. A three-story braced frame structure frequently falls in an inward/outward collapse. The top two stories collapse inward, back on top of the pancaked floors; the lower story collapses outward on to the sidewalk.

**Wall Collapse Warning Signs**

The 90-degree-angle wall collapse is often signaled by the corners of the falling wall splitting apart from the remaining walls. The lean-over collapse is often indicated by the burning structure slowly starting to tilt or lean to one side. An inward/outward collapse may not exhibit any structural warning at all-sometimes the only indication that a collapse is imminent is a serious fire burning for a long time on the lower floor. When such a collapse occurs, firefighters report that they see no signs but that they hear a sudden, loud cracking noise and feel a hurricane-like gust of wind on their backs as they turn to run from the falling structure.

Of the three types of wall collapses, the inward/outward collapse is the most dangerous because it is sudden, it gives no visible warning signs prior to failure, and, unlike most other building failures, it may involve the collapse of two, three, or four walls simultaneously. During a fire in a structure with masonry walls, it is rare that more than one wall will collapse at one

time. When a braced-frame wood building collapses, however, all four walls may collapse at one time.

The 4 wooden structure collapses that occurred in the 1980s where walls failed, an investigation showed they were located on corners and one was the end building in a row of three which stood next to an open lot. As the last building was unsupported at one end, it was, in effect, the same as a corner building. All four buildings were three stories high and a serious, long-burning fire had destroyed the first floor of the structure.

**Corner Wood-Frame Buildings**

Wooden buildings constructed side by side receive support and stability from the adjoining structure. If the lower floor of a wood building burns and one of the wood bearing walls is destroyed by fire, the structure will begin to lean to one side. Adjoining structures built up against a wood building can prevent such a fire-weakened structure from collapsing.

When weakened by a fire on a lower floor, however, a wood-frame corner building will collapse on its unsupported side into the street or an empty lot. The bearing walls of a wood structure, unlike those in any of the masonry construction types, are combustible and can collapse when exposed to fire. The side bearing walls on the first floor of a three-story wood building are two-by-four-inch wood studs spaced 16 inches on center, the same as the bearing walls on the second and third floors. Though the bearing wall studs of the first floor support more weight than the second- and third-floor wall studs, there is no compensation for the increased deal load, unlike some multi-story, masonry bearing-wall buildings, in which the lower levels of the bearing walls are thicker than the upper levels. Therefore, if a fire weakened the bearing wall studs of all three floors at the same time, the ground floor wall studs would fail first because they support more weight than the second or third-floor bearing wall studs.

Based upon these four New York City building collapses and other wood-frame building failures, it is apparent that the height of the structure affects its stability, Three-story wood-frame buildings collapse more frequently than one- or two-story wood-frame buildings.

**Causes of an Inward/outward Collapse**

Three factors contribute to the inward/outward collapse of a braced frame wooden building: fire destruction of bearing walls, failure at the mortise-and-tenon connection, and exterior wall overload. Unlike the exterior walls of the four other basic construction types (fire-resistive, non-combustible, ordinary brick-and-joist, and heavy timber), the bearing wall of wood-frame construction can be destroyed by fire and can collapse when flames spread out of a window and consume the outside or inside of this load-bearing wall. Burning wood-frame buildings exhibit a rapid fire spread. When the fire department arrives on the scene, both the wooden exterior walls and the structure's interior are often involved with flame. When wood buildings are built close together or when there is a common roof space running through a row of wood houses, fire spread will be extremely rapid and will probably involve more than one structure. In addition to placing hose streams in the interior of the burning structure, firefighters will need one or more hose lines to control exterior fire spread along the outside combustible walls and to protect exposures from radiated heat. A firefighter should know which of the four enclosing walls of a burning wood building are the load-bearing walls that support the floors and roof. Because these walls are interconnected, the interior floors will collapse if the bearing walls fail during a fire. Conversely, if the interior floors collapse, they may cause bearing wall failure.
In older urban neighborhoods, wood-frame buildings were built close together, with the bearing walls usually the side walls and the non-bearing walls the front and rear enclosing walls. This practice has changed in suburban communities. Private homes, built on large plots of land, are designed to have the larger area of the building face the street front, so the front and rear walls are load-bearing and the two side walls non-load-bearing. Condominiums and row townhouses have the same design.

During a fire in a suburban row of townhouses, if the floors inside collapse, the front or rear walls may collapse outward. In peaked-roof buildings, the bearing walls support the majority of the roof rafters that are parallel to the ridgepole. In flat-roofed wood buildings, the

bearing walls are usually the walls with the greatest dimension: the non-load-bearing walls have the shortest dimension.

**Mortise-and-Tenon Joints**

The structural framework of a braced-frame wooden building which collapses inward/outward consists of vertical timber corner posts and horizontal timber girders or girts at each floor level. The corner posts and girders are connected by mortise-and-tenon joints. When a braced-frame wood timber collapses, it fails at the weakest points--often the mortise-and-tenon connection. The mortise hole has removed the center section of the corner post timber and reduced its strength; the tenon end of the girder is only a fraction of the original girder's thickness and therefore has only a fraction of its strength. In addition to this design weakness, the connection can be destroyed by fire. Furthermore, unlike concrete and steel fastening, the wood mortise-and-tenon connection is susceptible to collapse by rotting. A vacant wooden building open to the elements can be quickly weakened by rotting structural components like the mortise-and-tenon connections.

**Exterior Wall Overload**

The exterior wall of a wood-frame building can be weakened by the weight of a metal fire escape landing and ladder. This heavy metal structure attached to the outside wall of a wood building is anchored to two-by-four inch wall studs behind the wood sheathing. The weight of the metal fire escape can exert a slight outward pull on the wall studs to which it is attached for support. This pull causes the wall studs to curve or bow slightly outward. The load above, supported by the curved wall studs, is no longer transmitted through the studs as an axial load (centered or evenly distributed) but becomes an eccentric load (off-centered or uneven). During a fire, the wall supporting a metal fire escape must be considered a structural danger. The weight of the fire escape will accelerate the collapse of a fire-weakened wood wall.

There are two types of masonry surfaces applied to outside walls of old wood buildings: A brick-and-mortar veneer wall can be attached to the wooden structure by thin strips of sheet metal, one strip every two square feet; or a thick stucco coating, spread on wire mesh, can be nailed to the old wooden surface of the building. These wall surfaces increase the collapse danger during a serious fire in a wood-frame building by adding considerable weight to the structure. As much as eight pounds per square foot of stucco and wire mesh have been found on a collapsed wall.

Brick veneer not only overloads a wall but also hides major structural defects of the wall. It can conceal an obvious collapse warning sign, such as the wood walls splitting apart, or hide the burning of the wood bearing wall behind it. These masonry wall coverings also contain the heat and flame inside the building, thus increasing the destruction of the structural framework.

**Lessons to Be Learned**

1. Burning wooden buildings of three or more stories collapse more frequently than burning one- or two-story wood buildings.
2. Wooden buildings located on a corner plot or standing alone are more susceptible to collapse when exposed to fire than wood buildings in the center of a row of similar buildings.
3. When a serious fire burns out the entire first floor of a three-story wood building, there is a danger of collapse.
4. Of the three types of wood-frame building collapses, the inward/outward collapse is the most dangerous. It gives no warning and can result in the simultaneous collapse of two or more sides of the structure.
5. Three contributing causes of wood-frame building collapse are fire destruction of bearing walls, the mortise-and-tenon joint of a braced-frame wooden building, and the overload of an exterior wooden wall.

6. Large buildings collapsing on top of smaller buildings cause the smaller buildings to collapse.

**Questions**

1. Which type of construction has concealed spaces not more than one story?

A. Braced frame
B. Ballon frame
C. Platform frame
D. Lightweight construction

Answer_____

2. Which one of the five construction types has combustible bearing walls?

A. Fire resistive
B. Non-combustible
C. Ordinary
D. Heavy timber
E. Wood construction

Answer_____

3. There is a danger of a triple-decker collapse when serious fire burns out which floor?

A. first floor
B. second floor

C. third floor
D. roof

Answer _____

4. True or false - Burning lightweight constructed buildings may collapse within 10 minutes of the arrival of the fire companies.

Answer_____

5. In addition to stretching hose lines to the interior of a burning wood building, a hose line will be stretched to protect exposures from what kind of fire spread?

A. Convection
B. Conduction
C. Radiation
D. None of the above

Answer_____

**Answers**

1. C; 2. E; 3. A; 4. True; 5. C