Fresno Fire Department

Building Construction Guide

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Table of Contents

PURPOSE

The Fresno Fire Department responds to a multitude of building types daily. A proper understanding of building construction techniques and the ability to identify and respond to changing fireground conditions are essential to safe and effective firefighting operations. The purpose of this guide is to provide a basic overview of building construction.

APPLICATION

This guide intended to follow industry recommendations and standards and was based largely on Los Angeles Fire Department Book 29 Building Construction. The Fresno Fire Department thanks innovators in the fire service for their contributions in keeping firefighters safe and trained.

INTRODUCTION

As architects and the building industry continue to design and build structures that vary in type, design, materials, and building methods, it has become increasingly important that members stay familiar with both basic and new concepts of building construction. Construction methods are constantly being replaced by new and more efficient and cost effective methods to construct buildings.

Unfortunately, new construction methods are usually NOT designed to assist fire suppression operations. Considering the cost of labor, equipment, and building materials, it is not economically feasible to build a structure in the same manner as during the period of conventional construction. Heavy timbers have been replaced by smaller dimension lumber, and petrochemical based compounds have replaced conventional building materials, regardless of building size.

As architects reduce the mass and change the chemical composition of building materials, we are losing one of our most valuable factors: **time**.

Basically, we tend to fight structure fires the same way we did 40 to 50 years ago. Hose lines are taken inside an involved structure, and holes are opened in roofs for ventilation.

So, are buildings the same as the buildings constructed during the 1920’s and 1930's? They are not even close! Therefore, Firefighters who can recognize the strengths and hazards of buildings and roofs will increase their efficiency and safety. A working knowledge of building construction not only provides the necessary expertise to conduct a quick and accurate size-up of a structure; it also provides the foundation for effective, timely, and safe fireground operations in the following areas:

- Structural Integrity
- Ladder Placement
- Forcible Entry / Search and
- Rescue
- Ventilation Feasibility

Structural Integrity

The effects from fire on a particular type of construction, building or roof, should be evaluated to determine the remaining time necessary to conduct safe fireground operations.

The integrity of a working surface (i.e., roof and floor decking) must be evaluated for safe operations.

Ladder Placement

Ladders should be placed to the strong area of a building. This results in stability and strength for ladder operations.

Special hazards such as facades must be recognized and avoided.

Figure 1 Ladder Placement

Forcible Entry/Search and Rescue

- What are the best avenues to enter the structure?
- What is the probable floor plan of the structure?

Ventilation Feasibility

Figure 2 - Truck Crew on Roof

Can a ventilation operation be safely conducted?

Safe routes of travel for personnel across a roof must be determined.

Additionally, the direction of structural members (rafters/joists) must be determined prior to initiating ventilation to enhance safe and effective cutting operations.

Size-Up

Mental evaluations can be developed based on current knowledge.

A plan of action can be formulated based on perceived factors (occupancy type, exposure, involvement on arrival, etc.)

A common definition of this well used term is as follows: "Size-up (estimate of the situation) is a mental evaluation that assists in determining a course of action and the methods necessary to accomplish a desired goal." Basically, a size-up consists of three operations as follows:

1. Analyze the situation.
2. Decide on a plan. (strategy)
3. Put the plan into operation.(tactics)

Now, let's focus on the first portion of size-up, "analyzing the situation." When this portion of a size-up is applied to a structure fire, one of the first considerations should be the type and construction of the building. These two factors will indicate:

- Rate of burning.
- Possible avenues of fire spread. (False ceilings, multiple attics, facades, etc.)
- Problems that will have a direct impact on efforts to confine a fire.
- Structural integrity.
- Time necessary to conduct safe fireground operations.

When these factors are quickly and confidently evaluated, a useful overview of the structure will result. Due to the fact that the building industry is continuing to construct various types of buildings in an endless combination of construction materials, methods and styles, identification of buildings and their related strengths and hazards can be challenging at best. Therefore, let's consider a simple method to visually size-up old and new construction methods and styles to assist in determining related strengths and hazards. Additionally, when conducting a building size-up, "***undress***" the building in your mind. Look past the exterior of a building and visualize what is INSIDE (strengths and hazards) the building. Our size-up will focus on the following areas:

- Construction Styles
- Roof Styles
- Construction Methods
- Metal Concrete
- Masonry
- Frame/Stucco
- Curtain
- Age of the Building.

CONSTRUCTION STYLES

Conventional Construction

Conventional construction utilizes structural members that depend on size for strength. The greater the span for a structural member, the larger it has to be to support a given load. Additionally, conventional construction does not usually depend on the sum total of all structural parts or members for its strength. Structural members depend on their size for strength.

SIZE = STRENGTH. This can be easily demonstrated by considering mill/timber construction. Structural members may be 8 x 8 inches for strength. The size of structural members dictates the time necessary for failure when exposed to heat or fire.

Lightweight Construction

Unlike conventional construction, lightweight truss construction does not derive strength from size. Strength is obtained from multiple members that are in compression and tension. The strength of the individual structural member is dependent on the total sum of the other members; therefore, if one member fails, others may fail.

COMPRESSION / TENSION = STRENGTH

(LESS THAN AVERAGE WEIGHT / SIZE)

Figure 3. Lightweight Construction Truss System

A single lightweight truss structural member can span 70-feet and may be comprised of 2 x 4's in compression and tension to form an integral unit. Although this structural member is strong, the size of the individual members is relatively small, requiring ***less*** time for structural collapse when exposed to heat or fire.
Let's briefly compare some of the major differences between conventional and lightweight construction and what can be expected when they are exposed to fire:

As previously mentioned, conventional construction does not rely on a sum total of members for strength. A simple example is a gable roof in a dwelling. The ridge board and rafters are an integral unit. However, they are separate and distinct from the ceiling joists. Therefore, when the attic is exposed to fire, the rafters and roof may collapse on the ceiling joists, thereby preventing collapse onto firefighting personnel below.

Lightweight construction is vastly different due to truss construction that depends on the sum total of members for strength. When a truss gable roof in a dwelling is exposed to sufficient fire, expect the rafters (top chord of the truss), the roof decking, and ceiling joists (bottom chord of the truss) to collapse as a unit into the structure, exposing firefighting personnel to falling, burning debris. There is no comparison between the size of the wood in conventional and lightweight construction. With few exceptions, 2-in x 3-in and 2-in x 4-in are the standard for lightweight construction, while conventional construction will utilize a minimum of 2-in x 4-in (and up to mill/timber construction).

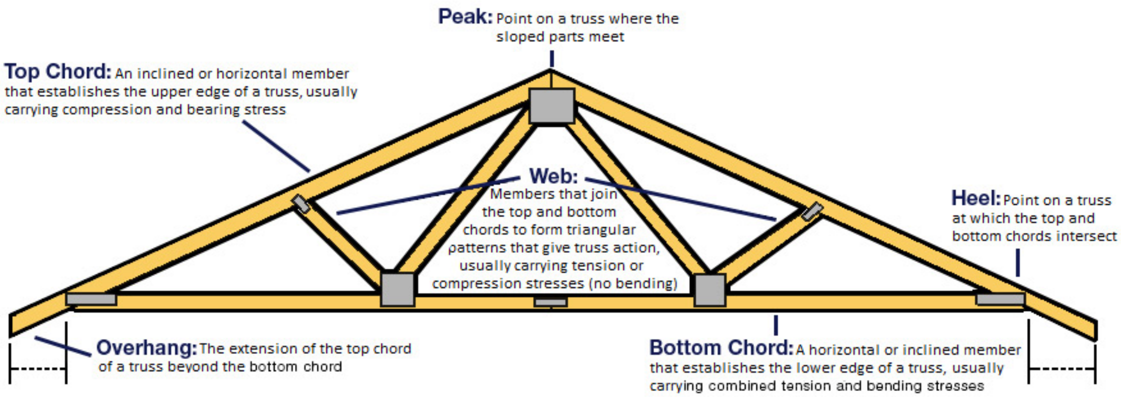

Figure 4. Common Lightweight Roof Truss

This translates into time that must be considered when deploying personnel and evaluating an offensive or defensive operation. Remember, the ability to accurately estimate the amount of time that a structure can be considered structurally strong is dependent on the following factors:

- Type of Construction
- How long the fire has been burning
- Fire Intensity

ROOF STYLES

For size-up considerations, roof styles can be divided into the following categories:

- Gable
- Hip
- Flat
- Bridge Truss
- Arch
- Sawtooth

Let's expand on each of these roofs and consider their construction, strengths, and hazards.

Gable Roof

A-frame configuration of conventional or ordinary construction that consists of a ridge board and rafters that cross the outside walls. Rafters are usually 2 x 6 inches or larger and are usually 16 inches to 24 inches "on-center."

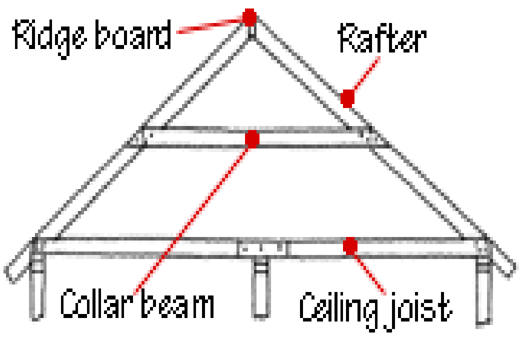

Figure 5. Conventional Roof System

Additional support is provided by collar beams and ceiling joists. This roof is found in semi-flat to steep pitch configurations. As detailed earlier in this section, 2 x 6 inch rafters (spaced up to 36 inches "on center" for steep pitched roofs) were commonly utilized for roof structural members. Additionally, the ridge was comprised of 1 x 6 inch ridge board or the lack of a ridge board which resulted in the 2 x 6 inch rafters butted together.

Lightweight construction utilizes 2 x 3, or 2 x 4 inch wood trusses held together by metal gusset plate connectors. Truss systems are enjoying widespread use in roof, floor and rough window and door openings. Trusses share common features such as top chords, bottom chords, and webbing.

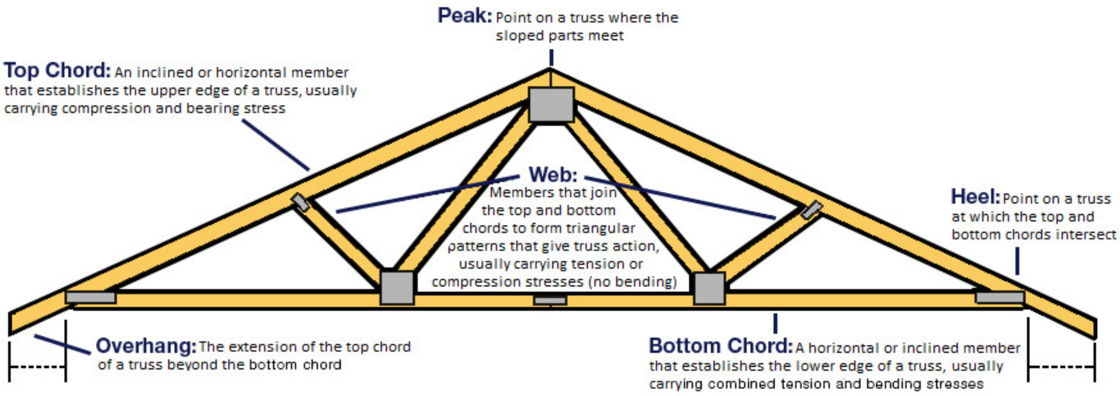

Figure 6. Common Lightweight Truss System

Metal gusset place connectors may vary in size, thickness, and depth of penetration. The most common are ***18 gauge steel plates with prongs that produce 3/8 inch*** penetration.

The bottom chord of the truss has replaced the 2 x 4 inch (or larger) ceiling joist found in conventional construction.

A point of interest with this type of lightweight construction (which also applies to open web and wooden "I" beam construction***) is the fact that truss members may only be supported at their outside edges*** (unless used as a cantilever truss).

Interior partition walls may not support the truss at any point along the bottom chord. Eighteen-gauge "roof truss clips" may be found nailed to the bottom chord (every three to five trusses) and top plate of interior walls. Roof truss clips provide some stability for interior partition walls. In this configuration, ***interior partition walls could be classified as "free standing."*** Common "on-center" spacing for truss rafters is **24 inches**.

Strengths

Conventional construction utilizes ridge boards and rafters of 2 x 6 inches or larger. This type of construction will last longer (compared to 2 x 4 inch trusses) when exposed to fire. The strong areas of this roof are the ridge and the area where the rafters cross the outside walls.

Figure 7. Conventional Construction Gable Roof

Hazards

The use of 2 x 4 inch rafters with no ridge board is similar in appearance, size and structural integrity to lightweight 2 x 4 inch trusses. This similarity will also apply to a reduced burning time and potential early failure rate and collapse of the roof.

Utilization of 2 x 3 or 2 x 4 inch trusses with metal gusset plate connectors equals a short burning time and potential early failure rate and collapse. Trusses are under tension and compression and when the bottom chord or webbing fails trusses will fail. Rapid collapse is common. When metal connector plates and surrounding wood are exposed to fire, the connector plates will quickly fail by pulling out from the wood.

The bottom chord of the truss has replaced the 2 x 4 inch (or larger) ceiling joist of conventional construction. Coupled with the fact that bottom chords may not rest on the interior walls (which offer additional support), expect collapse of the entire roof in a short period of time.

Newer roofs use 3/8 or ½ inch plywood as a decking instead of 1 x 4 inch or 1 x 6 inch space sheathing. Plywood will burn and fail at a faster rate than sheathing and offers minimal resistance to fire. Particle, chip and strand board are also currently utilized as a decking in an effort to reduce building costs and can be more hazardous than plywood.

Hip Roof

Similar to the gable roof; notice the lack of the A-frame configuration. Ends of the roof terminate in a "hip" configuration. Conventional or ordinary construction consists of a ridge board, hip rafters from the ridge board down to and across the corners at the outside walls.

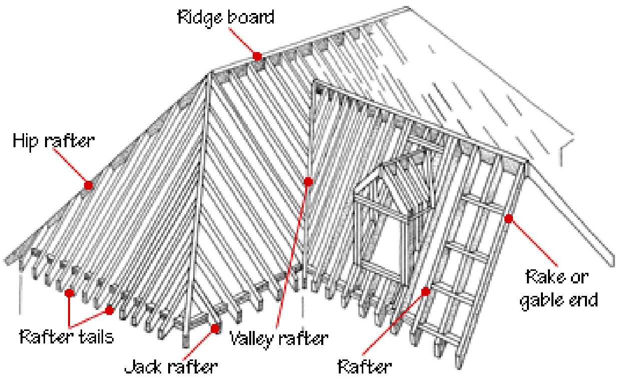

Figure 8. Hip Roof Conventional Construction

Valley rafters are utilized where two roof lines join together. Jack and common rafters complete the structural members. The ridge board and rafters are usually 2 x 6 inches or larger. Rafters are usually 16 to 24 inches "on center," similar to the gable roof. "Rough cut" 2 x 3 or 2 x 4 inch rafters 36 inches "on-center" was also utilized in older wood frame structures with steep pitched roofs.

In lightweight construction, construction methods are similar to those used for gable roofs. Various degrees of pitch are characteristic in this style of roof.

Strengths

Ridge board, valley rafters, hip rafters, and the area where rafters cross the outside walls are areas of strength. In conventional construction, ridges and rafters are 2 x 6 inches or larger.

Hazards

Similar to gable roofs. Utilization of 2 x 3 or 2 x 4 inch rafters or trusses will produce similar results to 2 x 4 inch rafters and lightweight trusses in gable roofs when exposed to fire. Roofs with a steep pitch may require roof ladders to conduct ventilation operations. If the roof is covered with tile or other similar materials, the roof will become slippery when wet and offers minimal footing when dry. Additionally, tile and other related materials need to be removed prior to roof ventilation operations.

Bridge Truss Roof

These roofs are found on various types and sizes of commercial buildings primarily constructed during the ***1930's and 1940's***. Wooden truss members are built from 2 x 12 inch lumber.

Figure 9. Bridge Truss Roof

This usually constitutes a heavy grade of construction. Metal tie rods may be used vertically for additional support. Rafters are 2 x 6 inches or larger and covered by 1 x 6 inch sheathing (diagonal or straight) and composition roofing material. ***Straight sheathing was utilized prior to 1933, and diagonal sheathing was utilized after 1933***. Plywood decking (installed over existing) is utilized, if modified for the Earthquake Ordinance.

Strengths

Well-constructed. When exposed to fire, early collapse of main structural members should not be a primary concern. However, depending on the type of fire***, this roof predictably fails in sections***. This roof is easily identified by its characteristic sloping ends.

Figure 10. Sloping Ends of Bridge Truss

Hazards

Strength is dependent on the size of lumber utilized and the span of trusses. The trusses are in tension and compression and ***may fail under severe fire conditions***. The underside of the roof is usually common to the interior of commercial warehouse type structures, or the bridge trusses can be modified to allow storage in the attic area or ceilings (the bottom chords can be covered with sheathing or plywood) (and/or lath and plaster, etc. can be attached to the bottom chord of the trusses. ***These factors can contribute to early collapse of the trusses and roof***. If the roof has been modified for the Earthquake Ordinance, ventilation personnel must be aware of plywood, metal straps and supports.

Bowstring Arch Roofs

Similar to the bridge truss roof. This popular type of roof was constructed during the 1930's, 1940's, and 1950's on both small and large commercial type structures.

Figure 11. Bow String Construction

Usually a large size (2 x 12 or 2 x 14 inch) of lumber comprises the arch trusses and related members. Some arch trusses have multiple beams forming one truss arch. Rafters are 2 x 6 inches or larger and covered by 1 x 6 inch sheathing (diagonal or straight) and composition roofing material. ***Straight sheathing was utilized prior to 1933, and diagonal sheathing was utilized after 1933***. Plywood decking (on top of the sheathing) is utilized, if modified for the Earthquake Ordinance.

Strengths

Most roofs of this type are well constructed. When exposed to fire, early structural collapse of the arched trusses should not be a primary concern. Similar to the bridge truss roof, it ***usually fails in sections***, depending on the type of fire and structural integrity of the roof.

Hazards

Strength is dependent on the size of lumber utilized and the span of trusses. The trusses are in tension and compression and ***may fail under severe fire conditions***. The underside of the roof is usually common to the interior of commercial warehouse type structures, or the arch trusses can be modified to allow storage in the attic area or ceilings (the bottom chords can be covered with sheathing or plywood) (and/or lath and plaster, etc., can be attached to the bottom of chord of the trusses. These factors can contribute to early collapse of the trusses and roof. If the roof has been modified for the Earthquake Ordinance, ventilation personnel must be aware of plywood, metal straps and supports.

Lamella Arch Roof

Lamella Arch Roofs are an egg crate, geometric or diamond-patterned roof, constructed from 2 x 12 inch wood framing with steel plates and bolts at junctions of framing. Roof decking is 1 x 6 inch sheathing and composition roofing material. This type of an arch roof is supported by exterior buttresses or internal tie rods with turnbuckles, and is common on gymnasiums, large buildings used for recreational activities, large supermarkets, etc.

Figure 12. Lamella Arch Roof

Strengths

Solidly built, with good construction techniques and lumber.

Hazards

Although these roofs offer some protection when exposed to fire, ***total roof collapse may occur if fire removes more than 20-percent of the roof structure***. Total roof collapse of the roof can result from ***"the domino effect"***.

Tied Truss Arch Roofs

Although this roof is similar in appearance to bowstring arch and lamella roofs, it is significantly different in that it is an arched roof that uses ***metal tie rods to offer lateral support*** for the walls of the building.

Tie rods (usually 5/8 inch in diameter) with turnbuckles are used below each arch member to ensure the arches do not push the exterior walls outward. Tie rods may pass through exterior walls outside plates, which facilitate identification of this style of roof. Proper tie rod tension is maintained by turnbuckles.

Top chords of arch member may utilize laminated 2-in x 12-in or large members. Rafters are 2-in x 10-in or larger and covered by 1-in x 6-in sheathing (diagonal or straight) and composition roofing material. Straight sheathing was utilized prior to 1933, and diagonal sheathing was utilized after 1933. Plywood decking (on top of the sheathing) is utilized, if modified for the Earthquake Ordinance.

Strengths

This type of roof utilizes a large size of lumber (2-in x 12-in or larger) and 1-in x 6-in sheathing as the roof decking.

Hazards

The primary hazard of this roof is early failure of the metal tie rods and turnbuckles. The tie rods, which are in tension, provide lateral support for the exterior walls and prevent the arches, which are in compression, from pushing the exterior walls outward and collapsing the building. ***Due to the fact that this roof (and its relationship to the building) is dependent on the strength and security of the tie rods, roof failure may occur in sections when exposed to fire***. However, the roof may be susceptible to total failure depending on the type of fire.

Sawtooth Roof

Used on commercial buildings to yield additional light and ventilation for manufacturing type occupancies.

Figure 13. Sawtooth Roof

It is constructed with rafters of 2 x 8 inches or larger and utilizes wood and/or metal supports for bracing. The sloping portion is covered with 1 x 6 inch sheathing (or ½ inch plywood in newer roofs) and composition roofing material. This type of roof is basically constructed the same today as it was during the 1930's and 1940's.

Strengths

Well-constructed. When exposed to fire, early collapse of main structural members should not be a primary concern. Additionally, this type of roof is easy to ventilate; utilize the hinged panes of glass.

Hazards

The underside of these roofs can be considered as open or exposed to the structure. Newer sawtooth roofs are covered with ½ inch plywood. Plywood decking will yield little resistance to fire. If this roof has been modified for the Earthquake Ordinance, ventilation personnel must be aware of plywood, metal straps and supports.

Conventional Flat Roof

Wood rafters of various sizes (2 x 6 inches and larger) are laid across outside walls, or outside wall to interior walls/structural supports. Rafters are covered with 1 x 6 inch sheathing or plywood (in newer applications) and composition roofing material.

Figure 14. Conventional Flat Roof

Some lightweight roofs are similar in design, but the rafters are replaced with lightweight construction, making it important not to mistake lightweight construction for conventional flat construction.

Strengths

Susceptibility to fire is totally dependent on the size of the rafters, their "on-center" spacing and the type of decking that has been utilized. ***Consider the perimeter of the building a strong point.***

Hazards

The degree of hazard is determined by the rafters, span, size, on-center spacing, and the presence of metal hangers used to suspend the rafters. If this roof has been modified for the Earthquake Ordinance, ventilation personnel must be aware of plywood, metal straps and supports.

Newer conventional flat roofs covered with plywood instead of sheathing will present a significant problem. Plywood which may be found in 3/8 inch to 5/8 inch thickness' offer minimal structural integrity under fire conditions. Plywood roof decking may be burned out (plywood "layers" comes when exposed to heat and/or fire) from the underside of the roof. ***New applications are utilizing "particle or chip board" for decking applications***.

Wooden I Beam Roof

Figure 15. Wooden I Beam Roof

Wooden I Beam construction consists of top and bottom parallel wooden chords that are connected by a wooden stem. The top chord, which is under a load, offers a bridging effect causing the top chord to be in compression and the bottom chord member to be in tension. Open web construction is prefabricated at the factory before installation.

Two-by-fours are used as chords, but 2 x 3 inch chords are common. Some chords may resemble plywood due to horizontal (or longitudinal) laminations. However, ***this is a trade lamination process that enables a low grade of lumber to be used for structural members***. The stem is joined to the top and bottom chords by a continuous glued-edge joint and may be constructed from 3/8 inch plywood or "chip-board" of the same thickness. When these prefabricated joists are installed in a building, top chord members can be secured (metal hangers) to the top of bearing walls with the bottom chord member remaining unsupported and away from the wall, or the bottom chord member can be secured to the top of bearing walls with the top chord unsupported and above the wall.

The common on-center spacing is 24 inches. Nailing blocks are placed perpendicular to the top chords and are spaced four feet apart. This provides an additional nailing surface for the 4' x 8' sheets of plywood.

Nailing Block

When plywood decking is nailed to structural members a method termed "diaphragm nailing" is employed. Prior to nailing, the plywood sheets are placed so the 8-foot dimension crosses the roof structural members, and the 4-foot dimension parallels the roof structural member. The joints of the plywood are then staggered (every 4') similar to a masonry wall.

Figure 16. Nailing Blocks

Strengths

Consider the perimeter of the building where the roof ties into the exterior walls a strong area.

Hazards

What there is to burn consists of 3/8 inch stem and 2 x 3 inch or 2 x 4 inch chords in tension and compression. It will take little time for the 3/8 inch stem to burn, weaken, and cause collapse of the truss chords and roof that has been sufficiently undermined by fire. Buildings will be found with open and unprotected chords. Common practice is to run heating and air conditioning ducts of various sizes through the stems which removes a significant percentage of the stem and gives fire horizontal access to adjacent "I" beams, assisting the travel and spread of fire. Due to the size of lumber and the chord members in tension and compression, ***expect rapid failure of this roof when exposed to fire***. Plywood will burn and fail at a fast rate and offers little resistance to fire. Ventilation personnel must be aware of nailing blocks when cutting between and parallel to the top chords.

Open Web Roof

Open web construction consists of top and bottom parallel wooden chords that are cross-connected by steel tube web members. The top chord (supported) which is under a load, offers a bridging effect causing the top chord to be in compression and the bottom chord member (unsupported) to be in tension.

Open web construction is prefabricated at the factory before installation and is constructed with either parallel chords laid on edge or flat laid chords. The steel tube web members are prefabricated from one to two inch cold rolled steel tubing with the ends pressed flat into a semicircular shape with a hole punched through the end. These flattened ends are inserted into slots in the chords and steel pins (up to one inch) are driven through the chord members and flattened ends of the web member, completing the assembly. Spans to 70-feet are possible using a single 2' x 4' or two 2' x 3's as top and bottom chord members. A single 2 x 4 up to 70 feet is made possible by joining different lengths in glued, mitered "finger joints."

Figure 17. Open Web Truss

When these prefabricated joists are installed in a building, top chord members can be secured (metal hangers) to the top of bearing walls with the bottom chord member remaining unsupported and away from the wall, or the bottom chord member can be secured to the top of bearing walls with the top chord unsupported and above the wall.

The common on-center spacing is 24 inches. Nailing blocks are placed perpendicular to the top chords and are spaced four feet on center. This provides an additional nailing surface for the 4' x 8' sheets of plywood. When plywood decking is nailed to structural members, a method termed ***"diaphragm nailing"*** is employed. Prior to nailing, the plywood sheets are placed so the 8-foot dimension crosses the roof structural members, and the 4-foot dimension parallels the roof structural member. The sheets of plywood are then staggered.

Strengths

Consider the perimeter of the building where the roof ties into the exterior walls a strong area.

Hazards

What there is to burn consists of cold rolled steel, 2 x 3 inch or 2 x 4 inch chords in tension and compression. It will take little time to burn, weaken, and cause collapse of the truss chords and roof that have been sufficiently undermined by fire. Buildings will be found with open and unprotected chords. Expect to find a lack of fire stops in this construction. Due to the size of lumber and the chord members in tension and compression, ***expect rapid failure of this roof when exposed to fire***.

Plywood will burn and fail at a fast rate and offers little resistance to fire. Ventilation personnel must be aware of nailing blocks when cutting between and parallel to the top chords.

Metal Gusset Plate Roof

Figure 18. Metal Gusset Plate

Wood trusses predominantly composed of 2 x 4's that are held together by metal gusset plate connectors. Trusses for roofs are constructed in a wide variety of shapes (flat, gable, hip, etc.) all shapes share common features.

Figure 19. Metal Gusset Truss System

Trusses consist of top chords, bottom chords and webbing (supports between the top and bottom chords). These trusses are held together by "metal gusset plate" connectors that vary in size, thickness and depth of penetration. Eighteen-gauge steel plates with prongs that produce ***3/8 inch penetration*** are common and used in a wide variety of applications. Utilization of 2-in x 4-in in a span of up to 80 feet may be found in flat metal gusset plate roofs. Decking material is usually ½ inch plywood. Dwellings will use 3/8-in or ½-in plywood.

Strengths

Consider the strong area to be where the trusses cross (cantilever applications) or terminate on the outside bearing walls.

Hazards

The material exposed to fire consists of 2-in x 4-in trusses chords in tension and compression with metal gusset plate connectors. It will take ***little time to burn, weaken, and cause collapse of the truss chords and roof that have been sufficiently undermined by fire***. Whether from connector plates that have pulled out or from deep char***, a truss or multiple trusses will fail***. In dwellings, rapid and total collapse is common.

Plywood will burn and fail at a fast rate and offers little resistance to fire. These roofs will often retain their shape as the plywood is burning through. Ventilation personnel must be aware of nailing blocks when cutting between and parallel to the top chords.

Panelized Roof

Figure 20. Panelized Roof

This roof may be found on wood, masonry or concrete tilt up slab buildings. It consists of four major components:

- Beams (laminated wood or metal)

- Purlins
- 2 x 4 inch joists
- 2 inch plywood decking

Figure 21. Panelized Roof Framing

After the walls are erected, the roof is usually constructed in the following manner: Laminated beams of various sizes (6 x 36 inch is common) are initially installed spanning the length or width of the building. Beams are supported at their ends by pilasters, wood or steel posts, or saddles. Wood or steel posts may provide additional support along the span. These beams are spaced between 12 and 40 feet apart. Beams may be bolted together to provide lengths well in excess of 100 feet. Supported by these beams, wooden purlins are installed with metal hangers on 8 foot centers (a sheet of plywood is eight feet long).

A common size for a purlin is 4 x 12 inches with the length depending on the spacing of the beam. Metal gusset plate trusses are beginning to be substituted for conventional purlins, resulting in substantial cost savings as well as an additional collapse hazard.

Hazards

Joists measuring 2 x 4 inches by eight feet are installed with metal hangers on 24 inch centers between the purlins, parallel to the beams. Sheets of 4 x 8 feet x ½ inch plywood are nailed over this framework. The plywood decking is then covered with composition roofing material.

Strengths

The strengths of this roof are:

- Beams
- Purlins

- Building Perimeter

Hazards

Beam span supports of 4-inch hollow steel pipe may be found. ***Expect weakening and/or collapse*** of these supports with ***failure of large portions of the roof under heavy fire*** conditions.

Figure 22. Panelized Roof, notice the nailing blocks and joist hangers

Moderate to heavy fire intensities will quickly burn through the 2 x 4 inch joists and 1/2 inch plywood decking, which may result in vertical travel of the fire and a reduction in horizontal fire spread. When the insulation (kraft paper) is subjected to fire or sufficient heat, the foil covering will peel away from the middle layer of tar impregnated paper. The ***paper will give off flammable gases that rise and build up between the insulation paper and plywood decking. When the ignition temperature of the gases is reached, the gases will flash, resulting in heavy char to the surrounding wood and burning insulation paper dropping to the floor below*** (which contributes to rapid spread of the fire). Fire is then able to expose the 2 x 4 inch joists and ½ inch plywood decking which offer little resistance to fire.

If lightweight trusses are utilized for the purlins, consider additional and rapid failure when the roof is exposed to fire.

Open Web Bar Joist Roof/Parallel Truss

Figure 23. Open Web/Parallel Truss

Open web bar joist construction utilizes a popular building material (metal) in a wide variety of buildings, large and small. Top and bottom chords are usually made from 1/8 inch steel and web supports are solid 5/8 inch steel bar. Large buildings may have bar-joists used as girders spaced up to 45 feet. Joists are spaced eight feet apart to accept corrugated metal decking covered by alternating layers of tar and tar paper.

These layers may also include a composition board or other type of material to provide insulation protection. Additionally, 4 x 8 foot sheets of ½ inch plywood with 2 x 4 inch joists are gaining popularity. This roof may have composition covering the decking.

Figure 24. Open Web/Parallel Truss

Strengths

Consider the perimeter of the building a strong area.

Hazards

Metal exposed to fire or sufficient heat (steel begins to lose its strength at 1000 degrees F) will expand, twist and possibly fail. Therefore, when the entire roof is comprised of metal, the short time necessary for roof collapse should be a major concern.

Lightweight Concrete Roof (Non-Structural)

A steel or wood sub-structure is covered by corrugated metal ("Robertson Decking"). An air-entrained mixture of sand, cement and, occasionally, pea gravel is pumped on top of the corrugated metal decking and 4 x 4 inch or 6 x 6 inch wire mesh to a thickness of three to four inches. Composition roofing material makes up the final layer. These roofs are utilized when additional insulative properties are desired (next to airports, freeways, etc.).

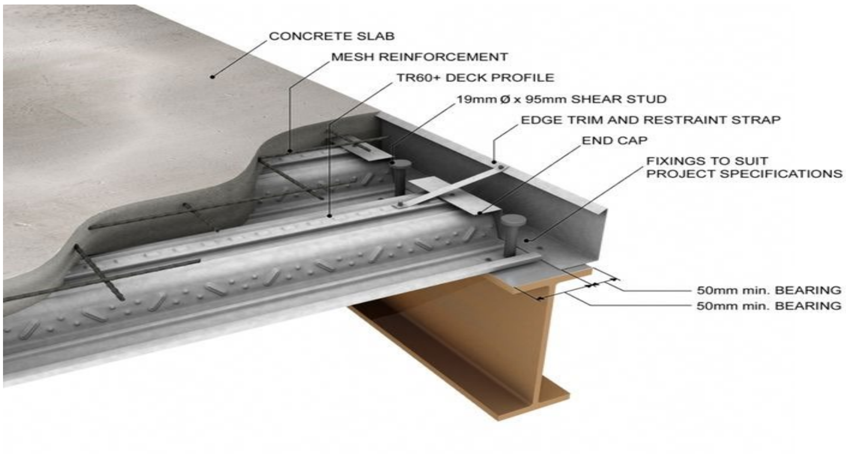

Figure 25. Lightweight Concrete Roof

Strengths

Lightweight concrete roofs offer a strong, hard surface. They are structurally sound and resistant to fire.

Hazards

Concrete roofs are difficult to penetrate with a chain saw or rotary saw with a masonry blade. ***Use a rotary saw with a diamond blade or carbide tipped wood blade to cut ventilation openings***.

METAL CONSTRUCTION METHODS

Buildings that are primarily constructed of metal can be categorized as follows:

Corrugated

These buildings utilize a sub-structure of wood or steel, covered with corrugated steel, aluminum or fiberglass. They are easily erected, can be utilized in various types of applications, and are easily identified by their characteristic "corrugated" appearance.

Figure 26. Corrugated Metal Roof

Hazards

The corrugated portions of these buildings will quickly fail when subjected to sufficient heat or fire. Remember, steel loses its tensile strength at 1000 degrees F, and aluminum or fiberglass offers little resistance to fire. ***Roof ventilation operations on these buildings should be considered extremely dangerous***.

Metal Beam

These buildings have a sub-structure of steel beams, usually coated with a sprayed on fire retardant material. This skeleton is then finished with an exterior of concrete, masonry, glass or similar materials.

This type of building will vary from two stories to the tallest high rise. Modern High Rise buildings and multi-story office buildings typify this type of building. Although structurally strong, consideration must be given to the type of fire, intensity of fire, and the type of building materials exposed to fire.

Figure 27. Metal Beam Structural Members

Hazards

Vertical extension of fire and smoke to upper floors is enhanced in buildings with multiple floors.

Falling panels of glass or other building materials.

What you see is "not what you get." Brick buildings that consist of brick construction offer both structural integrity and the lack of vertical extension through the walls.

However, newer buildings that appear to be of brick construction covered with brick veneer attached to lightweight construction. Pre-fire planning your area and being familiar with construction and specific buildings is the key.

When exposed to sufficient heat, ***metal beams can expand 9" per 100'*** which can push out walls, etc.

CONCRETE CONSTRUCTION METHODS

Tilt Up

These buildings are made of concrete slabs that have been "tilted up" into place to form exterior walls of a structure. These buildings are easily identified by their exterior appearance and can be up to five stories in height.

Figure 28. Tilt-Up Building Construction

Hazards

Expect to find lightweight construction in the interior walls, floors (if multiple story) and roof. Lightweight roof construction may be comprised of 2-in x 4-in or 2-in x 3-in in tension and compression and extensive use of ½ inch plywood. ***These contribute to rapid spread of fire and early roof collapse***. Ventilation operations on this type of roof are dangerous unless personnel are properly trained.

The modern "tilt up" with its characteristic flat roof has increased the popularity of the facade. The style of construction allows increased areas of fire spread and collapse potential that may threaten personnel close to the exterior of a structure.

MASONRY CONSTRUCTION METHODS

Buildings that have masonry as the prime material can be categorized as follows:

BRICK

One of the more popular building materials used in various types of buildings, old and new, is the common brick. Unfortunately, brick buildings that were constructed prior to the 1930's are significantly different, both in appearance and structural integrity than brick buildings built today. It is safe to assume that the masonry portion of brick buildings constructed before the 1930's are "an accident looking for a place to happen," while the masonry portion of brick buildings built after the 1930's are very stable and are constructed as follows:

Pre-1933

Brick buildings constructed up until the 1930's are commonly classified as ***unreinforced masonry*** buildings. These buildings, built prior to 1933, are of ordinary brick construction and present extreme hazards to firefighting personnel under fire or earthquake conditions. Masonry buildings constructed prior to 1933 have the following characteristics.

Figure 29. Unreinforced masonry building

Figure 30. Rafter Tie Plate in Pre-1933 Masonry Brick Construction. Also shown King Rows.

- Mortar consisting of sand and lime only, no cement.
- Lack of steel reinforcing rods ("rebar").
- Brick exterior walls about ***13 inches thick***.
- Parapet walls around the perimeter of a roof. Parapet walls can be three feet above the roof line, and five feet or more if used as a facade on the front of a building.
- Floor and roof joists that are ***"let"*** (penetrated or resting in a cavity) into the inside of the exterior walls.
- Straight roof sheathing.
- Roof and floor joists that are ***"fire cut"*** (ends were cut with an angle) so they would pull loose from the exterior walls during a fire and collapse into the interior of the building without pulling down the exterior walls.

Post 1933

After the disastrous Long Beach Earthquake of 1933, building codes were revised to provide better earthquake safety for new masonry buildings. The following revisions characterize the masonry buildings that were built after 1933:

- Exterior walls are required to be at ***least nine inches thick***.
- Masonry walls are required to be ***reinforced with steel "rebar".***

- All joists and rafters are required to be anchored to exterior walls. This is usually accomplished by bolting a ***"ledger board"*** to a masonry wall and attaching the joist and rafters to the ledger board with metal hangers.
- Cement utilized in the mortar.
- Diagonal roof sheathing.

Post 1959

After the Tehachapi Earthquake of 1959, building codes were modified to require the following retroactive correction on existing buildings masonry construction:

- A four to six inch concrete bond-beam cap to be laid on top of lowered parapet walls along public ways and exits.
- Parapet walls should not be higher than 16 inches including the bond-beam cap.
- Exterior walls drilled at the roof rafter level and a steel anchor bar/rod installed every four feet and attached to the existing roof rafter. This modification rendered the fire cut of the roof rafter ineffective. The steel anchor bar/rods are secured to the exterior of the building by a plate/nut combination that is known as "rafter tie plates".

Figure 31. Post 1959 Masonry Construction Rafter Tie Plate

Post 1971

The Sylmar Earthquake of 1971 provided the impetus to further modify existing buildings of unreinforced masonry construction. A Committee was formed to evaluate these buildings and review current building codes. That review was instrumental in additional retroactive corrections (EARTHQUAKE ORDINANCE) designed to prevent exterior walls from collapsing outward by stabilizing the building by:

- Anchoring walls to floor and roof systems.
- Strengthening roof construction (plywood, metal straps, etc.)

Brick Identification

Unreinforced masonry buildings will share all or a portion of the following trademarks:

- Rafter tie-plates on the exterior of a building (rafter tie-plates can be found on remodeled "new" appearing buildings). These exterior plates on a masonry building indicate that the joists and rafters of the building are anchored to the exterior walls.

- A bond-beam cap of concrete on top of parapet walls. Concrete bond-beams may also have been added for strength over the windows and between the second floors of multi-story buildings. This is a common technique used for additional strength for exterior walls.

- Deeply recessed window frames. Window frames are "set" to the inside of the wall, thereby exposing about eight-inches of brick return on the exterior of a building. Remember, these walls are at least 13 inches thick.

- Windows may have arched or straight lintels.

Figure 32. Masonry Window Lintel

- The lime mortar between the bricks is white, porous, sandy, and may be easily rubbed away by a fingernail, knife, etc. In some cases, the bricks have not been uniformly laid and the workmanship appears sloppy.

- In every fourth to seventh row of bricks, one row will have been laid "on-end."

- This row of bricks is referred to as the "king row" and is for additional strength.

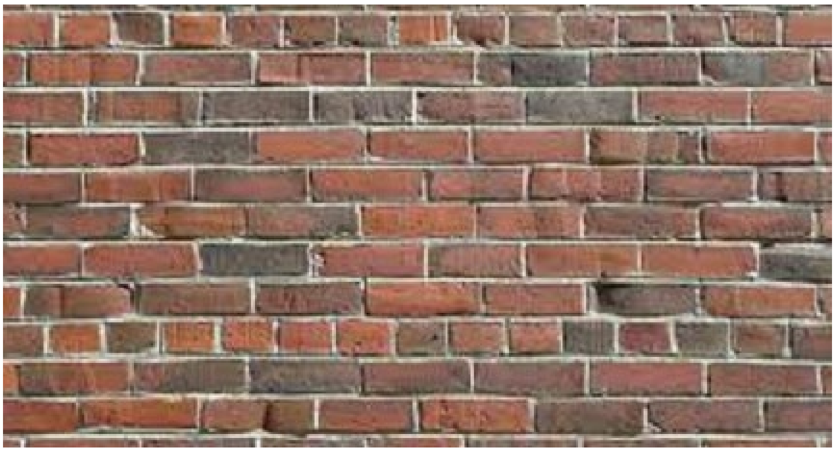

Figure 33. Brick Masonry King Row

Some unreinforced masonry buildings have a fancy or better quality brick on the front of the building to improve the appearance. However, utilizing the preceding trademarks, the following indicators can be easily identified:

- Recessed windows
- Bond-beams over the windows
- Rafter tie plates

Additionally unreinforced masonry buildings are required to be reinforced to comply with the Earthquake Ordinance. Modifications may include the following:

- Add steel bracing from parapet walls to roof structural members.

Figure 34. Steel Bracing Added to Parapet Walls

Metal straps across the width of the roof and attached to opposing walls. The straps are usually 1/3 of the length of the building back from the front and rear walls.

Remove the layers of composition and cover the sheathing with ½ inch plywood. This decking is then recovered with composition.

Hazards

The primary hazards of this type of construction are as follows:

Wall, roof, and floor collapse. Unreinforced masonry construction that is held together with lime, mortar, and sand creates a weak wall; particularly after the lime mortar has deteriorated with age and/or is subjected to heat from a fire. These buildings were originally designed so that floor and roof joists would pull out from the walls during a fire, thereby preventing wall collapse. When rafters or joists are anchored to the walls, collapse is enhanced during fire conditions.

An additional collapse hazard can result from arch type roofs (***bowstring, tied truss and lamella***) on unreinforced masonry construction. When arch roofs (particularly the bowstring and tied truss) are modified as per the Earthquake Ordinance, the additional roof stability provided by plywood and metal straps can increase the potential for collapse of front/rear walls.

A collapsing truss that is connected to the "HIP" rafters at the ends of these buildings will push the hip rafter outward , also pushing the corresponding wall outward with considerable force.

Considerations

Personnel and apparatus placement. Due to the presence of arch roofs that have been modified as per the Earthquake Ordinance and floor/joists rafters that have been anchored to the walls, exterior walls may suddenly collapse (during fire conditions) outward a distance that is equal to at least the height of the wall. The primary danger from collapse is the front and rear walls of a building. The secondary danger from collapse is the side walls of a building. The safe areas are as follows:

1. The corners of a building.

2. A distance at least equal to the height of the walls away from a building.

Placement of personnel and apparatus should be a primary concern when confronted with this type of construction.

During retrofit modifications, consider:

- Vertical openings.

- Holes in floors and ceilings.

- Building materials in hallways.
- Stairs removed.
- Metal straps across the width of the building and three to four feet from walls are hard on power saws.
- Decking comprised of sheathing, plywood, and composition. The extra "thickness" of the decking will not enhance "feeling" the rafters with a power saw.

Block

These buildings are primarily concrete block that form the exterior walls. This type of construction is strong and extensively utilized.

Hazards

It is common to find this type of construction supporting lightweight floor joists and roofs (depending on the age of the building). Facades are also common on this type of construction.

FRAME / STUCCO CONSTRUCTION METHODS

These buildings are used in a wide variety of applications, old and new. Although they are structurally sound, the stucco exterior walls can support extensive remodel additions and/or conventional or lightweight construction. The difference in construction can be detected by a prior knowledge of the building (pre-planning) or recognizing the difference between an "old or new" style of building.

Figure 35. Frame Construction and Fire Blocks

Hazards

- Vertical spread of fire through the walls is a possibility (if balloon construction is present). However, this is controlled by horizontal fire blocking if present.
- Lightweight construction. The age of the building is a key factor in identification of this construction.

Facades

A facade can be defined as an "identifiable style of construction on the exterior of a building that will conceal and spread the travel (extension) of fire." To summarize, facades are external attics.

Style

Currently, this style of construction is enjoying widespread popularity across the country. Facades are utilized to conceal equipment and machinery on flat roofs. As the popularity, utilization, and complexity of the facade increases, so does its impact on firefighting operations.

The following four areas should be considered when confronted by this construction:

<u>Overhang</u>

Consider the distance a facade extends from the building (A). As the size or extension from the building increases, so should concern about structural stability when a facade is exposed to fire. As the size of a facades increases, so does its complexity and the materials utilized in this construction. The size of a facade will have a direct effect on the area (what there is to burn) and the path and travel (extension) of a fire. Additionally, the extension of fire will be affected by the presence or lack of "fire stops."

Figure 36. Large Facade with Overhang

Facades are usually open or common to the attic of a building. This is common along with a lack of fire stops in the facade. Unless proven otherwise, expect any facade to be not fire-stopped and open to the attic of the building. Additionally, if a facade is exposed to fire, ***expect the facade to collapse outward at least the distance of the overhang of the facade***.

Figure 37. Facade without Fire Stops, notice the uninhibited fire travel.

Figure 38. If Facade is involved with fire, ensure that the entire facade is opened up to check for fire extension and stop fire travel.

Facade Height

Facade height (B) and shape will affect stability, the amount of building material utilized, and the potential path of fire. Two additional areas to consider are roof line and laddering operations.

On buildings without facades, roofs such as sawtooth, arches, etc. can be observed from the ground. This is helpful (and often necessary) when laddering a building and when considering roof ventilation operations. Consider what effect a facade will have on ground operations.

Supported or Unsupported

The structural stability of a facade will be enhanced if supported (C) by pillars, posts or other means that are often used for style of decoration.

Height from the roof

When confronted by a facade, an area that is often neglected is the distance from the facade to the actual roof line. Facades normally hide or conceal the roof line.

Perimeter

Facades are usually constructed on the portion of the building that is seen as the building is normally approached (the front and part of the sides). It requires extra money to construct a facade around the sides and back of a building. If possible, consider laddering that portion of the building without a facade. A good ***size-up*** for ladder placement is mandatory.

Scuppers

Roofs that are lower than a facade utilize scuppers for drainage. The scupper is the actual roof line.

Figure 39. Scuppers with Parapet Wall

Attic Vents

Roof lines are between the attic vent and top of the facade or parapet.

Equipment on the Roof

Equipment that can be seen above a facade will indicate the roof is in close proximity.

Windows

Roof lines are between the top of windows and the top of the facade or parapet.

Rafter tie plates

Rafter-tie-plates will indicate the location of roof rafters and will identify the roof line.

BUNGALOW AND BALLOON CONSTRUCTION

These buildings were constructed during the 1920's, 1930's and 1940's, and are primarily utilized in single family dwellings and multi-story habitational occupancies up to four stories.

Hazards

- Increased exposure problems due to all-wood construction.

Bungalow Construction

"Rough-cut" 2 x 4 inch studs and rafters were commonly utilized during the construction of these structures. Of particular interest was the utilization of 2 x 3 or 2 x 4 inch rafters for roof structural members and a ridge that is comprised of a 1 x 6 inch ridge board (the 2 x 4 inch rafters are butted together). This type of construction can be classified as an "old type" of lightweight construction. Additionally, due to the age of these buildings, the presence of termites, multiple layers of composition on the roof, and various types of remodels will affect the structural stability of this type of construction.

Balloon Construction. Although these buildings can be considered structurally sound, they often hide "balloon construction" which does not utilize horizontal fire blocking in the walls and plates between multiple floors separating the attic from open vertical runs in the walls. Platform construction utilizes fire blocking in the wall (studs which eliminate open vertical pathways to the attic). Balloon construction will quickly assist the travel of fire up the walls and into the attic, creating additional considerations.

Figure 40. Balloon Frame

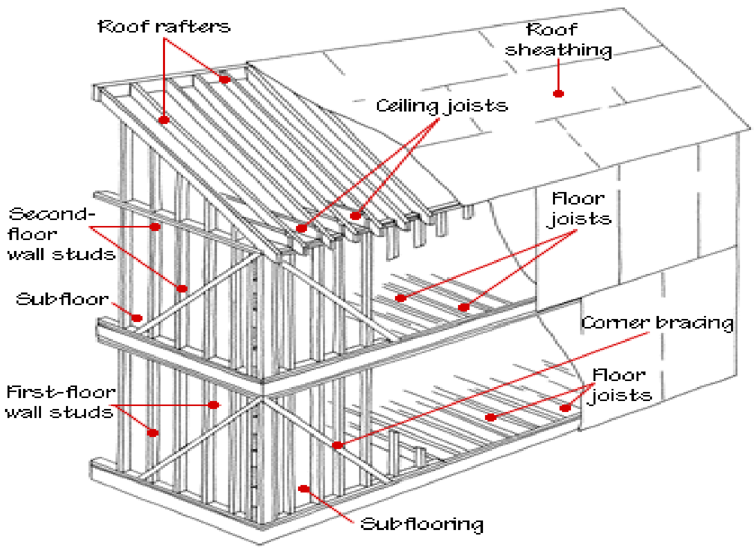

Figure 41. Platform Frame

Knob and Tube Wiring. Prior to the use of conduit and romex, a pair of wires were run throughout a structure to provide electricity to the various rooms. These wires are suspended on ceramic insulators and pass through ceramic tubes when it is necessary to run the wires through studs or plates.

Due to the age of this type of construction, the insulation has hardened, become brittle, and in many cases has fallen from the wires, leaving the wires exposed which presents an obvious electrical hazard to personnel opening walls or ceilings during fire suppression operations. When this type of construction exists, particular emphasis must be placed on eliminating the electrical "service" to the involved structure.

Figure 42. Knob and Tube Wiring

CURTAIN CONSTRUCTION METHODS

This method has dramatically cut the time necessary to complete the multi-story and high-rise buildings by bolting pre-fabricated panels on the exterior of buildings.

Generally, a skeleton is constructed of steel beams. Pre-fabricated panels made from materials such as lightweight concrete, slate, granite, fiberglass, glass panels, etc., are bolted into place utilizing metal brackets on the panels that mate to metal brackets on the steel beams of the building. These panels can also be bolted to sheet metal or aluminum outriggers/struts that are attached to the steel beams.

Once the decorative panels have been installed, glass panels or windows are installed to complete the exterior of the building. Once the exterior of the building is completed, the interior can be completed without interference from the weather. Depending on the particular method that is employed, "curtain" construction can be about 60% faster than conventional construction.

Figure 43. Curtain Construction Glass Opening

Hazards

Steel exposed to fire or sufficient heat begins to lose its ***structural integrity at 1000 degrees F***. **Aluminum exposed to the same conditions will lose its tensile strength and possibly fail in a shorter time period**. Because exterior panels are structurally dependent on metal brackets or struts, expect exterior panel failure when this type of construction is exposed to fire.

Large glass panels have replaced conventional windows. Glass panels can also be expected to fail when exposed to fire or sufficient heat.

Identification

Identification of this type of construction is facilitated by:

- Pre-fire planning.
- Recognizing the "cube" or "smooth" look.

AGE OF THE BUILDING

When approaching any buildings, consider its AGE. What is the building telling you about its construction? Is it lightweight construction or masonry with unreinforced walls? Three general time periods that can be used to classify buildings as follows:

Pre-1933

Structures built during this time period are characterized by the following:

- Unreinforced masonry. Roofs on these buildings are constructed using conventional methods. However, the brick walls are inclined towards sudden and early collapse if exposed to significant fire.

- Structures that utilize the wood shiplap exterior, balloon and bungalow construction and knob and tube wiring.

- Straight or diagonal roof sheathing.

1933 to Late 1950's

- Expect to find buildings with solid construction and in compliance with building codes.

- Straight or diagonal sheathing.

1950's to Present

- New style buildings with concrete-tilt up walls, facades, and flat roofs indicate that lightweight construction may be present.

With a basic knowledge and familiarity of construction, roof styles, construction methods, and the age of the building, a foundation will be laid to assist in developing a structure size-up that assists in effective ventilation operations and enhances safety. Additionally, fireground operations, communications, and resource deployment will be improved.

IMPACT OF LIGHTWEIGHT

CONSTRUCTION ON FIREGROUND DECISIONS

The implementation of lightweight construction within the building industry has resulted in a significant impact on fireground decisions when personnel are confronted with a structure fire that utilizes lightweight construction.

To ensure effective and safe fireground operations, personnel must address four areas:

Identification

The presence of lightweight construction must be identified.

This is accomplished by pre-fire planning, familiarity with a district, recognizing the style and age of a building, and proper communications between fireground personnel.

Communication

There must be a flow of information between incident commanders, company commanders, and other personnel that may be affected by a particular type of construction.

Time

Construction size and configuration directly effects fireground time. It is imperative to determine how much time is left to ensure the safety of an intended operation and selecting an appropriate method or operation to safely accomplish a task.

Operations

When the preceding factors are evaluated, a foundation will be formulated to determine the appropriate and safe implementation of interior, exterior, offensive, or defensive operations.

DEFINITIONS

Fire Cut - ends cut into an angle to allow the joist to fall into the structure in the event of a fire to prevent wall collapse.

Ledger Board - A narrow horizontal board to attach a row of studs to support the ends of a floor or ceiling joists.

Let - Joist is penetrated into or resting in a cavity of exterior walls.

Parapet Wall - A **parapet** is a barrier that is an extension of the **wall** at the edge of a roof, terrace, balcony, walkway or other structure

Petrochemical - Relating to or denoting substances obtained by the refining and processing of petroleum or natural gas. In building construction, the presences of gasoline type substances.

Rafter Tie Plate - steel anchor bar/rods are secured to the exterior of the building by a plate/nut combination

Size Up - a mental evaluation that assists in determining a course of action and methods necessary to accomplish a desired goal.

REFERENCES

Standard Operating Procedures:

Section 202.002b, Residential Structures, Garage

Section 202.003, Commercial/Big Box

Section 202.023a, Center Hall Construction

Section 202.024, 1-2 Family Residential Structures

Guides:

High Rise Guide