BUILDING CONSTRUCTION

Table of Contents

INTRODUCTION

As with many other sections in this manual, the most important reason for understanding building construction is safety. If fire fighters are unable to comprehend the type of building construction, associated terminology, and type of roof, they will not know when it is no longer safe to remain in or on the building. Fire fighters may also communicate incorrect or insufficient information to a building construction expert, possibly making his recommendations inappropriate. For these two reasons, fire fighters must comprehend the basics of building construction and how a fire in a particular structure can be dealt with in order to successfully contain it. Knowing common building construction terminology will allow fire fighters to understand and interpret building construction experts that may be called to a structure fire. Fire fighters must also have an understanding of the major roof types and comprehend their associated strengths and weaknesses. When attacking a fire, this knowledge will facilitate the opportunity to avoid serious injury or fatalities because of the possible hazards that may be peculiar to a particular roof type. A firefighter’s fundamental knowledge of building construction is an essential component of the decision making process in successful fire ground operations

Buildings may collapse for a variety of reasons including stress, poor construction, or deterioration. Fire fighters should be aware of the potential and imminent indicators of building collapse. They should be able to inspect a building and identify those indicators that may lead to a collapse, under normal conditions and during fire scene operations. Fire fighters must know what to do under these circumstances and when it is no longer safe to remain in, on, or near the building. An example might include the steady build-up of the water level when fighting an interior structure fire. It may be possible to reduce the amount of water on the floor by either knocking out the lower windows at floor level or by drilling holes in the floor.

Another important aspect of building construction fire fighters must be concerned with is the classification system of building construction and the basic differences between each type. Buildings vary in type, design, and building methods and each will have its own unique fire problems and hazards. Therefore, fire fighters who are familiar with the type of building classification and its construction basis, (i.e. - identifying those structural elements which may influence the spread of fire in buildings), will do a better job of containing the structure fire while ensuring fire fighter safety.

Objectives

- Identify and describe common terms utilized in wood frame construction.
- Identify major types of roof styles and construction.

- Describe the indications of potential building collapse that might be noted during inspections or prefire plans. This may include the following:

    a. Obvious cracks on masonry walls.
    b. Steel angle iron used to reinforce walls.
    c. Deteriorated mortar and bricks.
    d. "Stars" used with steel rods to brace walls.
    e. Unprotected steel beams and trusses.
    f. Wood I-beams.
    g. Heavily laden floors.

- Describe the indications of imminent building collapse that might be noted during an emergency. This may include:

    a. Ankle-deep water on the floors.
    b. Holes in the floors.
    c. Sagging floors.
    d. Sliding sheets of plaster.
    e. Rising plaster dust.
    f. Steel beams exposed to intensive heat and fire.
    g. Spongy floors and roof.
    h. Burned out trusses.
    i. Creaking, cracking or other sounds associated with structural failure.

- Identify design causes of structural collapse and some major warning signs of potential structural collapse during fire operations.

- Identify the five major types of building construction, and the amount of fire protection each provides.

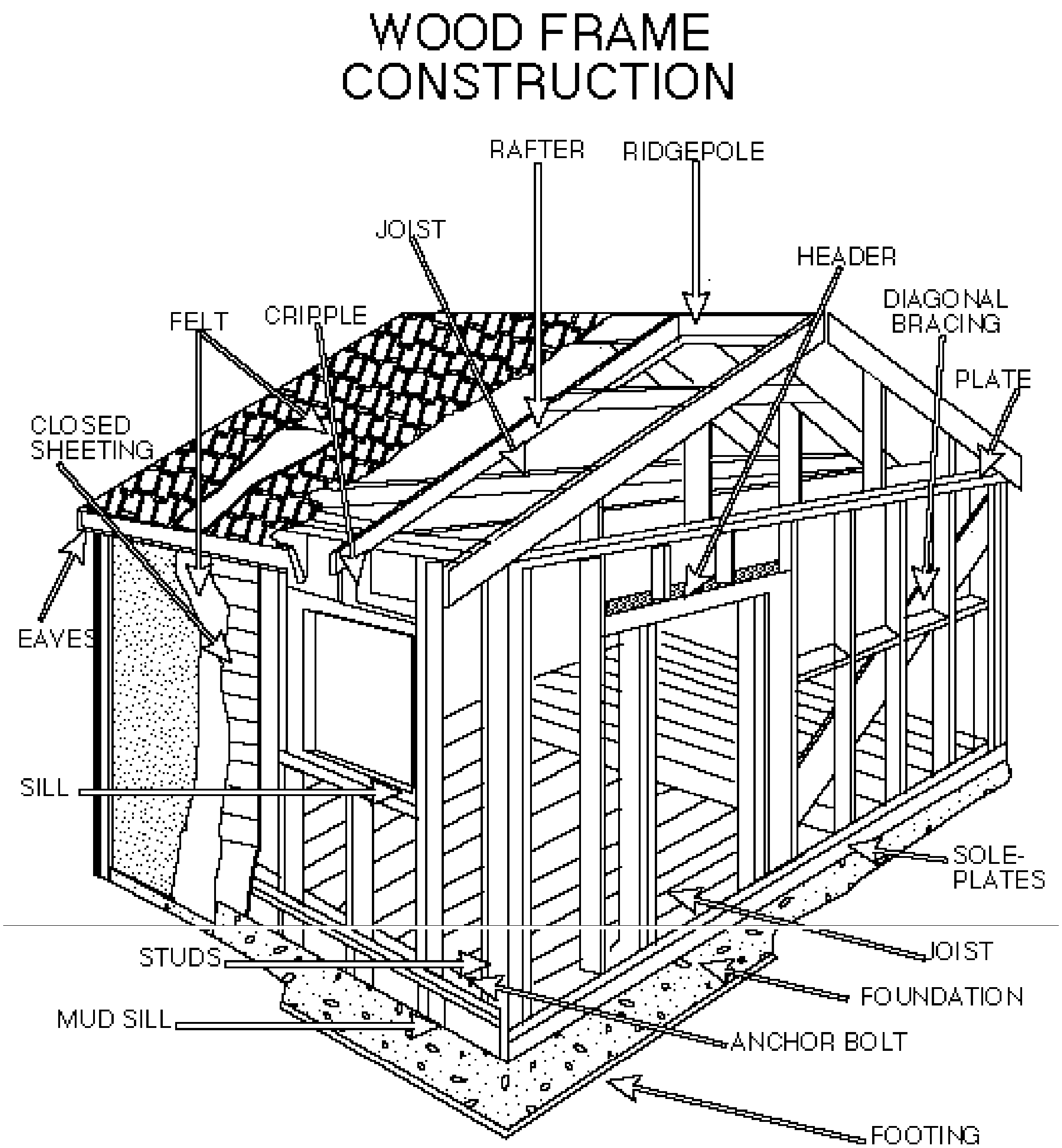
- Recognize and describe various types of walls found in typical building construction.

- Identify the structural features which may influence fire spread and safety, which would include:

    a. Fire walls, doors, windows, shutters, partitions, and stops
    b. Curtain boards
    c. Venting devices (smoke and heat)
    d. Fire exits and escapes
    e. Fire and smoke dampers

TERMINOLOGY

The dwelling cutaway on the next two pages overviews examples of construction terminology and techniques that are useful in developing a basic knowledge of construction fundamentals.



DEFINITIONS OF WALL TYPES

Bearing Wall: A bearing wall is capable of supporting a vertical load, such as a floor or a roof, in addition to its own weight.

Nonbearing Wall: This wall is not designed to support a vertical load.

Exterior Wall: An exterior wall separates the interior from the exterior of a building. Such a wall is usually exposed to the outside, though not always. It forms the extent or boundary of the building.

Interior Wall: This wall will be wholly within a building and will not be exposed to weather.

Party Wall: A party wall usually separates two buildings of distinct ownership and lies on the lot dividing line between the two properties. This wall can be either bearing or nonbearing.

Fire Wall: This type of wall is erected to prevent the spread of fire. It must have sufficient fire resistance to withstand the effects of the most severe fire that could occur in the building. It must also provide a complete barrier to the spread of fire. Any openings in this type of wall must be properly protected.

One Hour Wall: This is a term often used in the fire service. There are numerous different methods to construct a typical one-hour wall as described in California Building Code. A typical one-hour wall will be nonbearing and will consist of either:

a. 2" x 4" wood studs, 16 inches centered, with both sides covered by one layer of 5/8" type "X" gypsum wallboard.

b. 3-1/4" "Tin Can" metal studs, 24 inches centered, with both sides covered by one layer of 5/8" type "x" gypsum wall board.

Partition: This is an interior wall, one story or less in height, that separates two areas. A partition can be either bearing or nonbearing. Fire Partition - This is a partition that will inhibit the spread of fire but does not qualify as a firewall.

Curtain Wall: A curtain wall is an exterior, nonbearing wall more than one story in height. The curtain wall is supported by the structural frame.

Panel Wall: This is an exterior wall one story in height. In a multistory building, panel walls must be supported at each floor level.

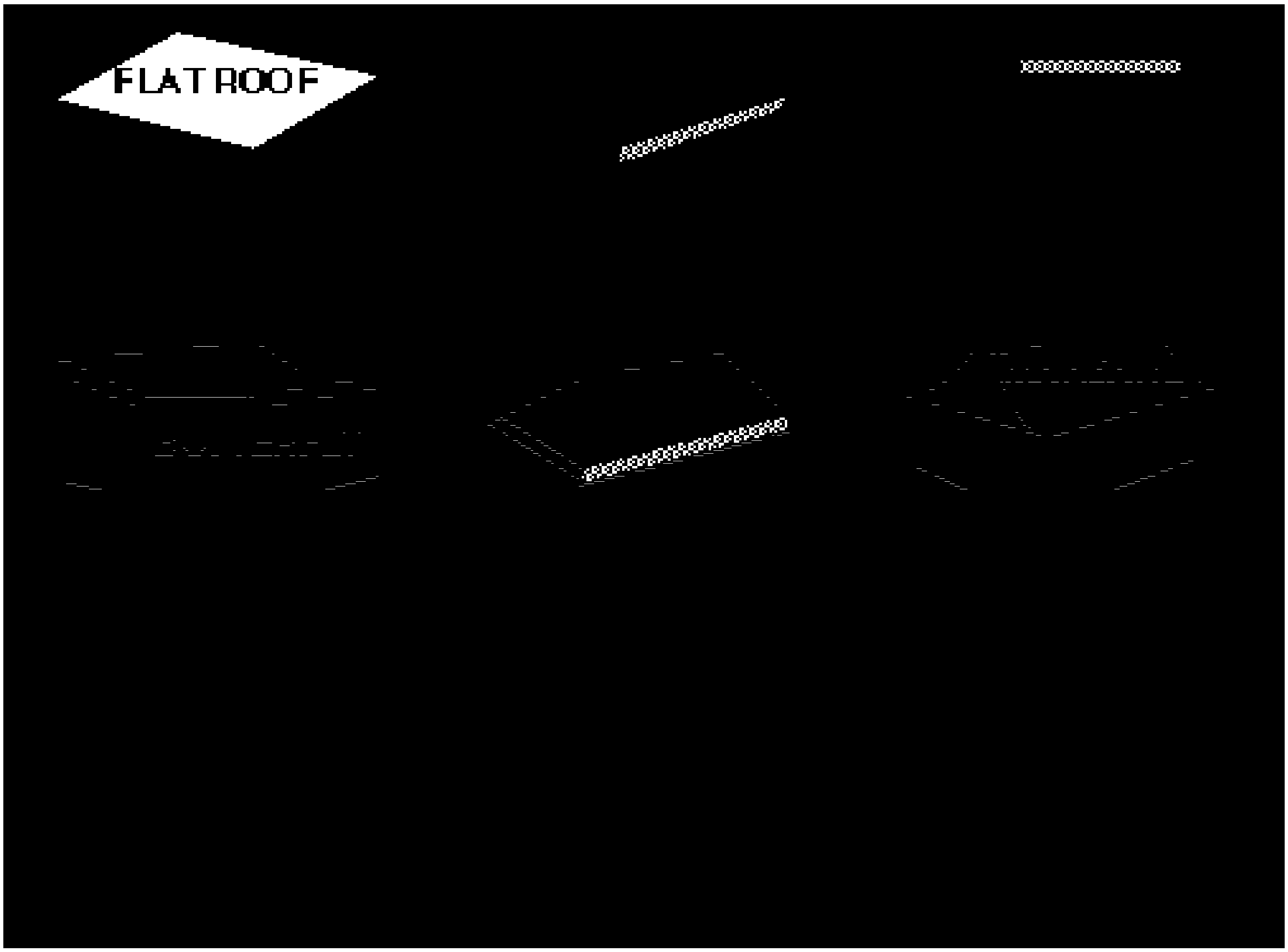
Parapet Wall: This is defined as the portion of wall that extends above the roof of a building.

Shear Wall: This type of wall is erected to assist in resisting the force of wind. It is built within the building and usually is part of some required enclosure such as an elevator or stair shaft. This is a bearing wall.

Veneer Wall: This is an exterior wall created to improve the appearance of a building. It is constructed from a variety of materials including marble, brick, stone, or steel. The most common veneered wall is brick on a wood frame. These walls are unsupported and are only as strong as the underlying wall. During a fire, these walls can become very unsafe.

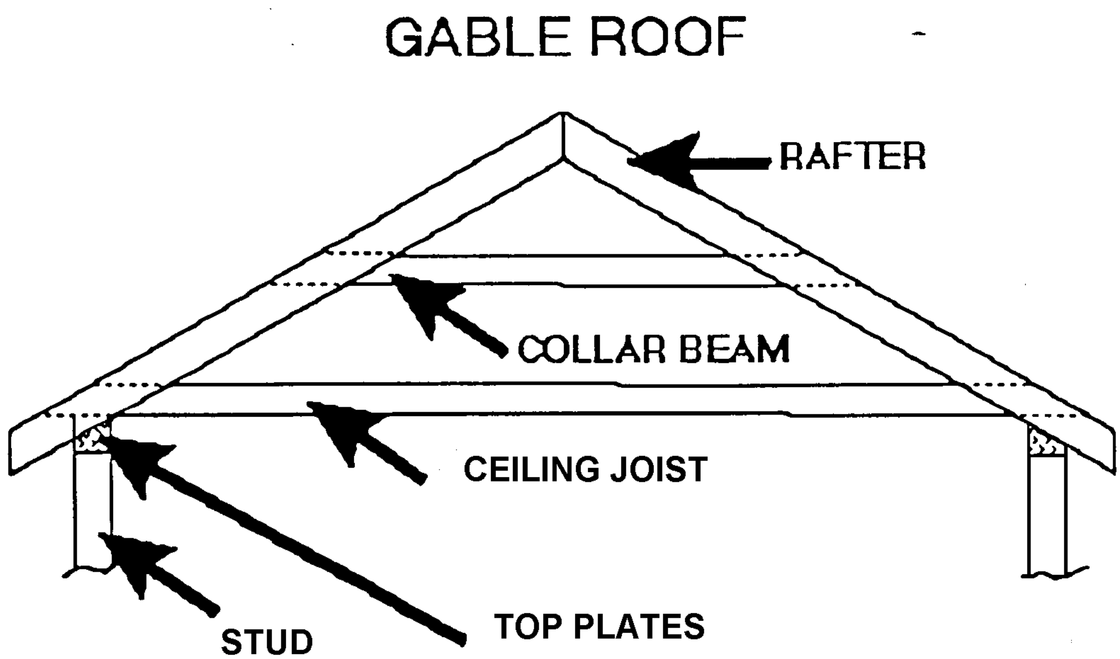
BASIC ROOF TYPES

The following roof types will summarize the majority of different types of roofs found within the City of San Marcos and surrounding areas. There are several others, but in general they are a variation of these types. Each type will be covered in detail within this section.



Gable Roof

Description: "A" frame configuration. Conventional or ordinary construction consists of a ridge board, rafters from the ridge board down to and across and outside walls (studs). Ridge and rafters are usually 2 X 6-inches or larger. Rafters are usually 16 inches to 24 inches "on center." Additional support is provided by collar beams and ceiling joists. Roof is constructed in semi-flat to steep pitches.

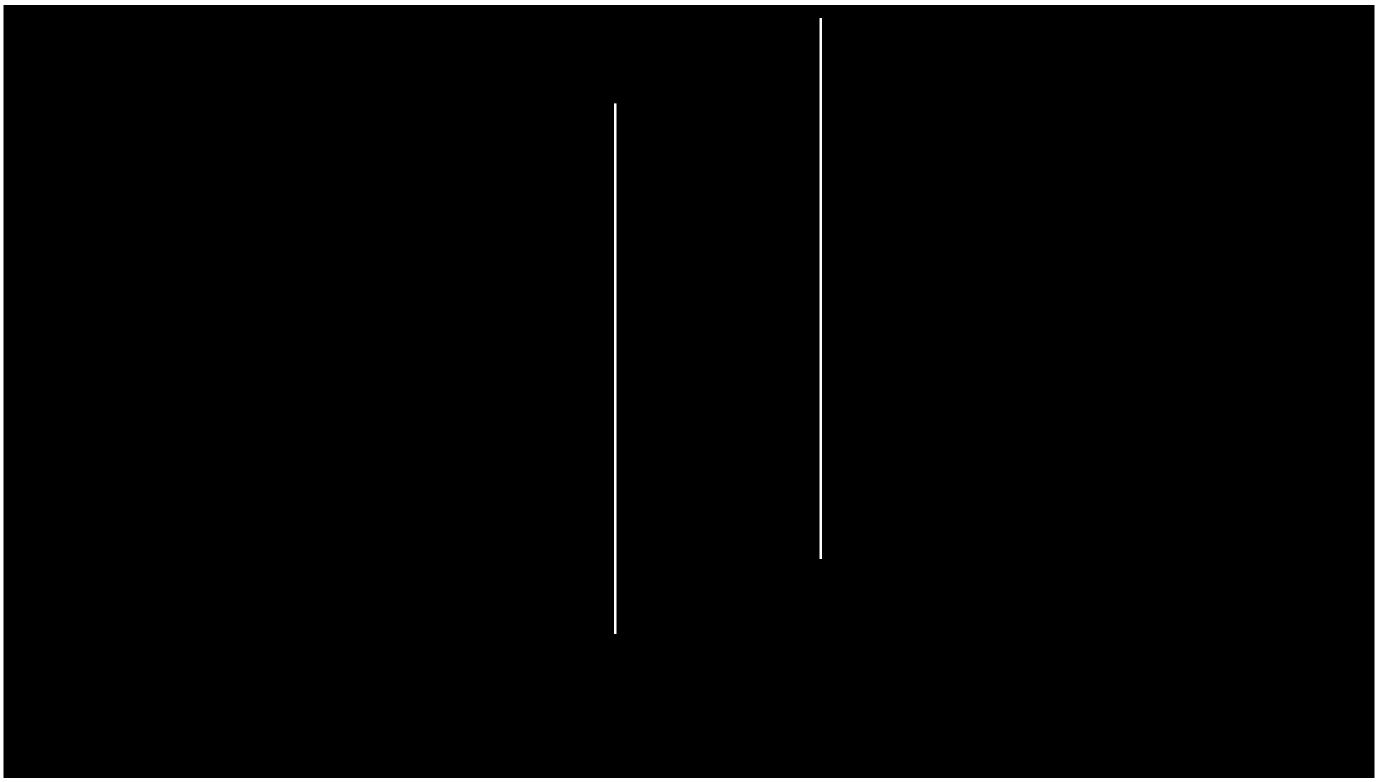


Strengths: Ridge board, rafters (if 2 X 6-inches or larger) and the area where rafters cross the outside walls.

Hazards: Older gables may use 2 X 4-inch rafters. Newer roofs use 3/8- or 1/2-inch plywood as a decking instead of 1 X 4-inch or 1 X 6-inch stripping. Plywood will burn and fail at a faster rate, offers little resistance to fire, and is difficult to remove for ventilation purposes.

Hip Roof

Description: Similar to gable roof, but no "A" frame configuration. Ends of roof terminate in "hip" configuration. Conventional or ordinary construction consists of ridge pole (board), hip rafters from the ridge pole down to and across the corners at the outside walls. Valley rafters are utilized where two roof lines are joined together. Ridges and rafters are usually 2 X 6-inches or larger. Rafters are usually 16 to 24 inches "on center". Various degrees of pitch are utilized.

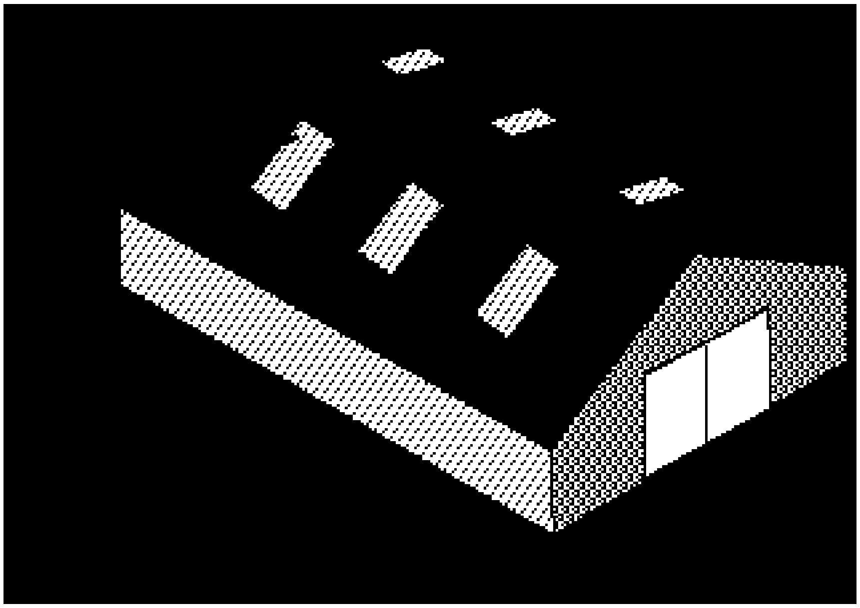


Strengths: Ridge pole, valley rafters, hip rafters, and the area where rafters cross the outside wails.

Hazards: Similar to gable roofs, utilization of 2 X 4-inch rafters and 3/8- or 1/2-inch plywood as a decking. Roofs with a steep pitch will require roof ladders to conduct ventilation operations. If roof is finished with tile, roof becomes slippery when wet and offers little footing when dry.

Corrugated Roof

Description: Fast and inexpensive to erect whether large or small. Corrugations consist of steel, aluminum, or fiberglass over a wood or metal substructure' Corrugated steel is often utilized, usually 18 to 20 gauge thickness. (About the thickness of an American car fender, .0475".)



Strengths: Ridge and area where roof crosses the outside bearing walls.

Hazards: Corrugations may be steel, aluminum, or fiberglass. Expect rapid failure of these materials when exposed to heat or fire. Some buildings utilize plastic or fiberglass panels in the roof as skylights. Personnel should consider this roof extremely hazardous for ventilation operations.

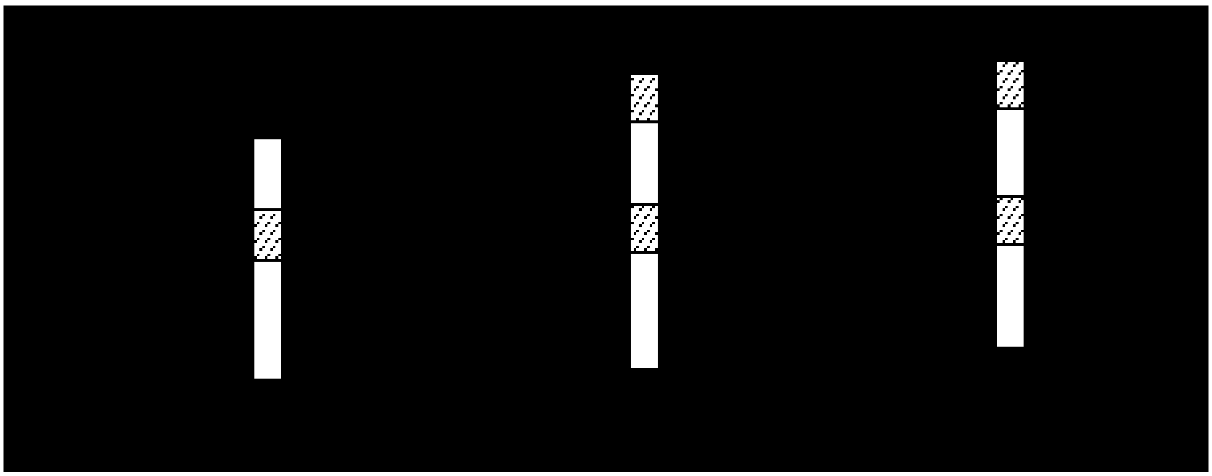
Lightweight Concrete - Nonstructural Roof

Description: Steel or wood substructure 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 wire mesh to a thickness of about 3 to 4 inches. Composition/roofing material is utilized as a final layer.

Strengths: Lightweight concrete surfaces offer a strong, hard surface that is structurally sound and resilient to fire.
Hazards: Difficult to penetrate with chainsaw or circular saw. Removal of skylights or horizontal positive pressure ventilation should be first consideration for ventilation. Use of a circular saw with a carbide blade is recommended when it’s necessary to cut.

Sawtooth Roof

Description: Constructed in commercial buildings to yield additional light and ventilation. Constructed with rafters of 2 X 8-inches or larger, and utilizes wood and/or metal supports for bracing to provide additional strength. Vertical portion is usually "wired" glass with operable panes. Sloping portion is covered with 1 X 6-inch sheathing or plywood and composition roofing material.



Strengths: Substructure constructed from adequate (2 X 8-inch, 2 X 10-inch, etc.) lumber. Easy to ventilate -- open the hinged panes of glass. Consider the area where rafters cross or are tied into the vertical walls as strong areas.

Hazards: Newer sawtooth roofs are covered with 1/2-inch plywood. Plywood decking yields little resistance to fire.

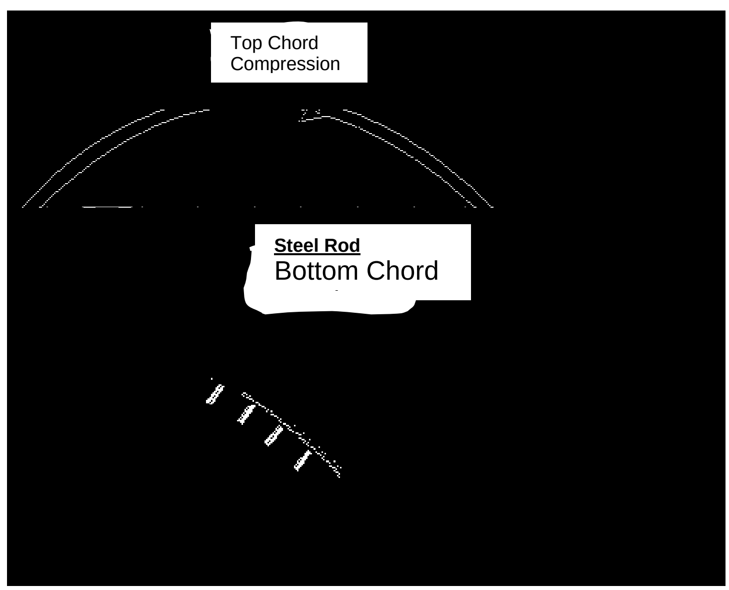
Bridge Truss Roof

Description: Wooden truss members constructed from 2 X 12-inch lumber with sloping ends. Metal tie rods may be used vertically for additional support. Joists are 2 X 6-inches and 2 X 8-inches and covered with 1 X 6-inches sheathing and composition roofing material.

Strengths: Well constructed. Consider the perimeter of the building (where trusses and the roof are anchored to outside bearing wall) and the bridge truss members as strong areas.

Hazards: Dependent on the size of lumber utilized and span of trusses. Trusses are in "tension" and "compression" and will fail under severe fire conditions. If metal tie rods are used, early failure of rods will affect the stability of the trusses.

Bowstring Arch Roof



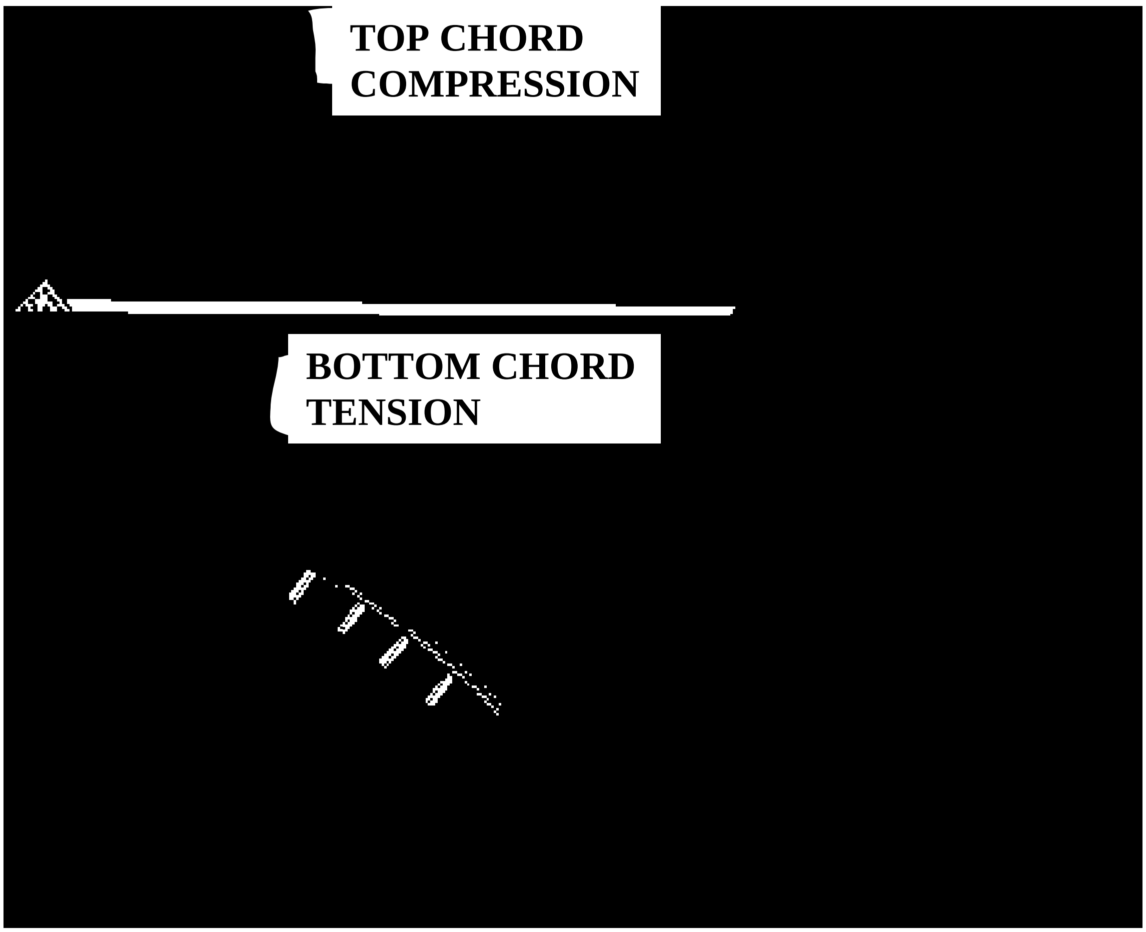
Description: Arch roof with tie rods and turnbuckles offering lateral support. Tie rods with turnbuckles are used below each arch member to support the exterior walls. Tie rods may pass through the exterior wall to an outside plate facilitating identification. Tension is maintained by turnbuckles. Top chords or arch members may utilize laminated 2 x 12's or larger. 2 X 10-inch rafters are covered by 1 X 6-inch sheathing and composition roofing material.

Strengths: This roof utilizes a good size of lumber and 1 X 6-inch sheathing as the roof decking. Consider the perimeter of the building and the bowstring arch members as strong areas.

Hazards: The main hazard is early failure of metal tie rods and turnbuckles. Tie rods (tension) provide lateral support to the walls and keep the arches (compression) from pushing the exterior walls outward, and prevent collapse of the building.

Ribbed (Trussed) Arch Roof

Description: Usually large size (2 X 12, 2 X 14-inch) of wooden members utilized to construct truss arch. Some arches have multiple laminated beams to form one arch. Rafters (2 X 10-inch or larger) are covered with 1 X 6-inch sheathing and composition of roofing material.

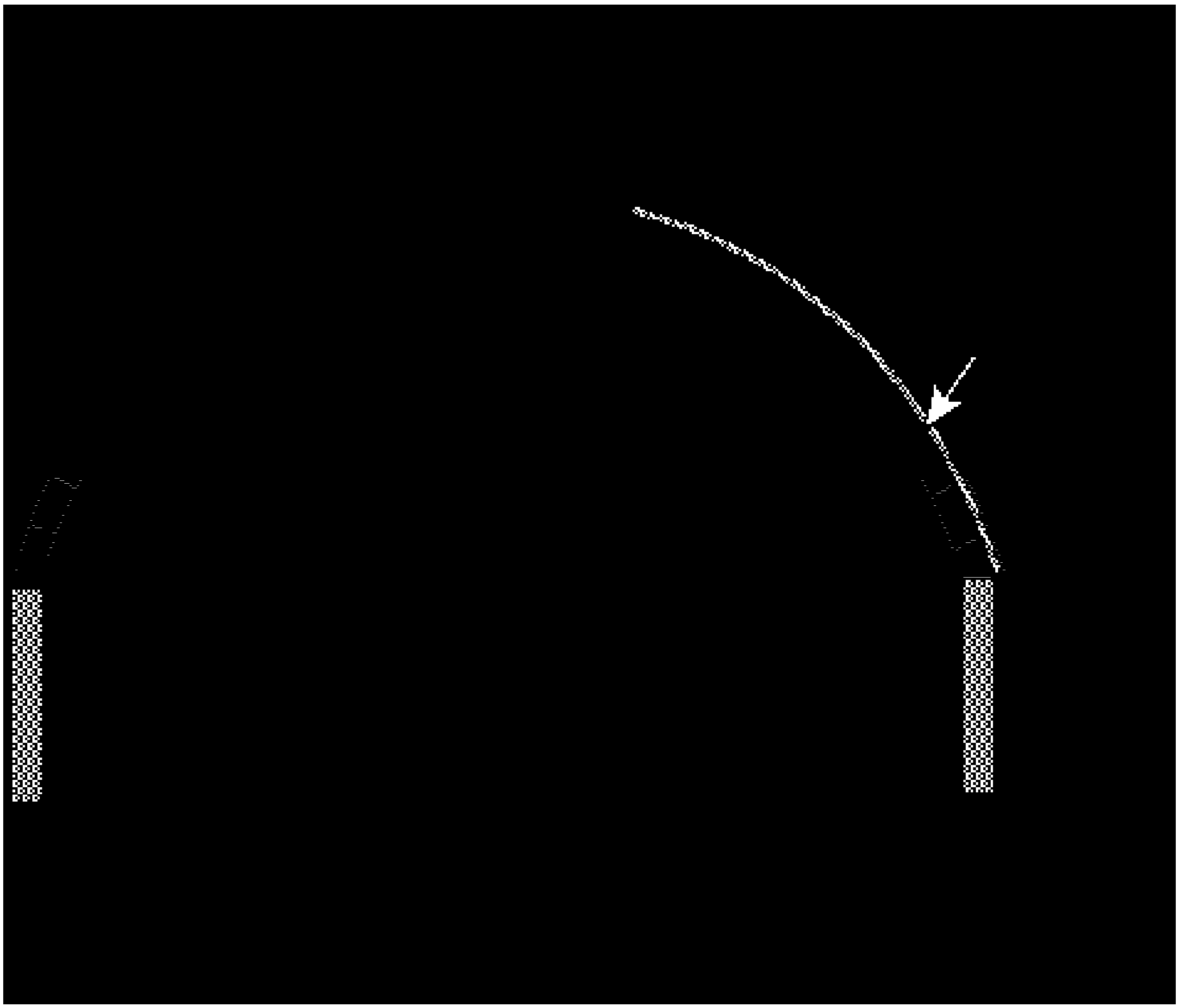


Strengths: Most roofs of this type are well constructed. Consider the perimeter of the building and the trussed arch members as strong areas.

Hazards: Determined by size of lumber and span of arches. Most roofs of this type are well constructed.

Lamella (Summerbell) Roof

Description: Egg-crate, geometric, or diamond-patterned roof. This roof is commonly known as a "Summerbell Roof", however, it is lamella roof construction constructed by the Summerbell Company. Constructed from 2 X 12-inch wood framing, steel plates, and bolts at junctions of framing. Roof decking is 1 X 6-inch sheathing and composition roofing material. Arch roof is supported by exterior "buttresses" or internally by tie rods and turnbuckles.

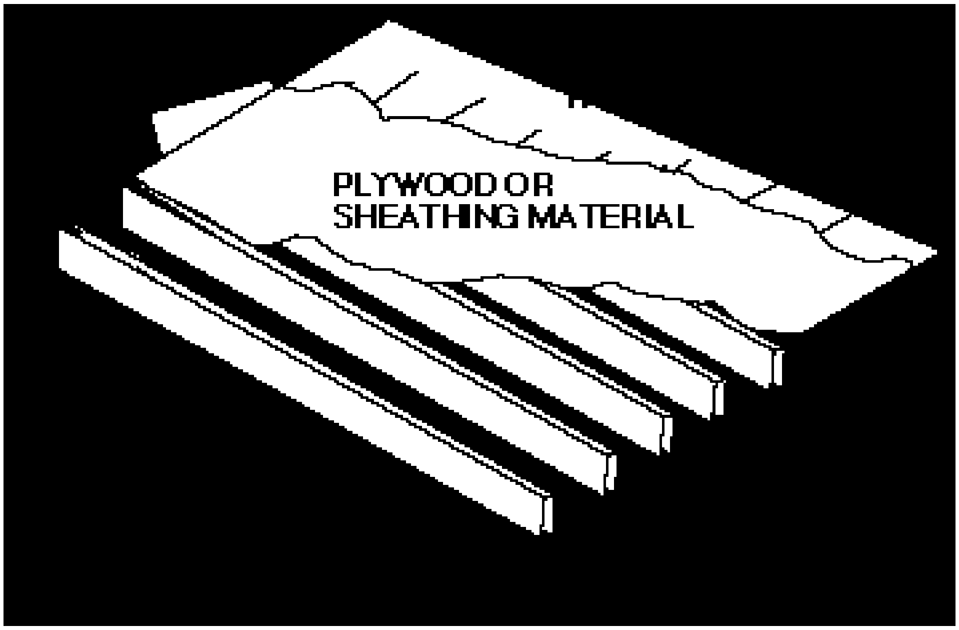


Strengths: Good construction utilizing solid construction techniques and lumber. Consider the perimeter of the building as a strong area.

Hazards: Possible total roof collapse if fire removes more than 20 percent of roof structure. Collapse may occur from the "domino effect."

Conventional Flat Roof

Description: Wood joists (or rafters) of various sizes laid across the outside walls or outside walls to interior walls or structural supports. Metal hangers may also be used to suspend joists. Joists are covered with 1 X 6-inch sheathing or plywood and composition roofing material. This is a very common roof type.



Strengths: Dependent on the size of the joists and type of decking utilized. Consider the perimeter of the building as a strong area.

Hazards: Degree of hazard presented by joists is based on span, size of joist, "on-center spacing," and if the joist is suspended by metal hangers. Roofs covered with plywood instead of sheathing present a problem. Plywood may be found in 3/8- to 5/8-inch thickness. Plywood offers little structural integrity under fire conditions and is difficult to remove for ventilation purposes. Also, plywood may be burned out from the underside and not show signs of weakness from the top of the roof.

LIGHTWEIGHT CONSTRUCTION METHODS

Lightweight building and roof construction is currently very popular with architects and building contractors across the country, and for good reason. Considering the present cost of labor, equipment, and building materials, it is not economically feasible to construct buildings the same as 50 years ago. Ease of installation and utilization of lightweight building materials have become the standard during the last 25 years. Heavy timber, laminated beams, and 1 X 6-inch sheathing have been replaced by 2 X 4's and half-inch plywood, regardless of building size. As modern architects reduce the size of what there is to burn, today's fire departments are losing one of their most valuable fireground factors--TIME.

This section will focus on the four major types of lightweight roof construction: panelized, metal gusset plate trusses, open web construction, and wooden "I" beams.

NOTE: This type of construction may also be utilized in floors, walls, etc.

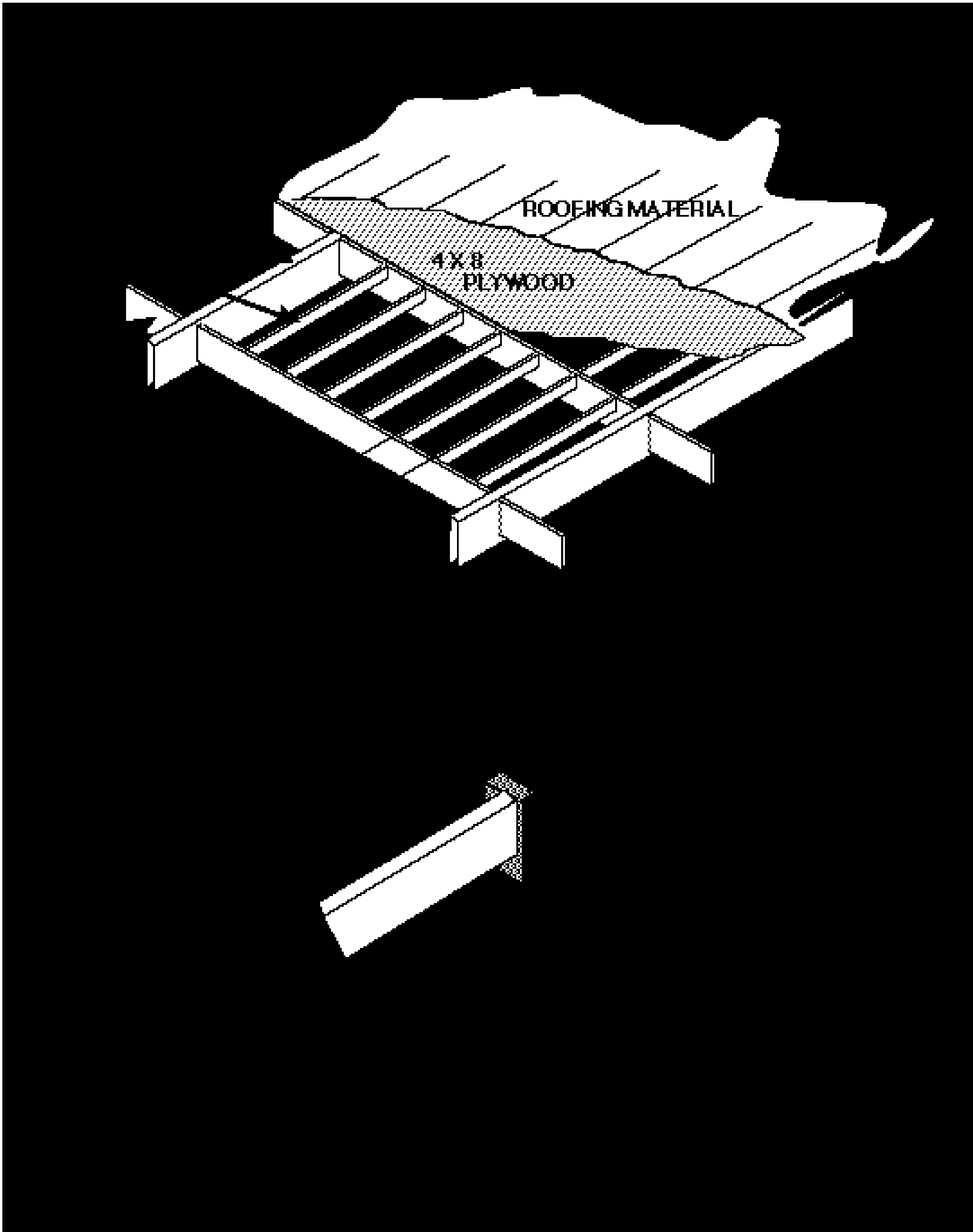
Panelized Roof System

Description: This roof can be found on structures constructed of wood, masonry, or concrete tilt-up . This roof consists of four major components:

a. Laminated beams
b. Purlins
c. 2 X 4 inch joists
d. 1/2 or 5/8 inch plywood decking

Panelized roofs do not have a space between the ceiling and underside of the roof occupied by the familiar trussed joist construction. The main structural support of the roof is accomplished by the use of laminated beams of various sizes (6 X 36 inches are common). The beams are supported at their ends by pilasters or posts and additional posts may be supporting the beam along the span. The beams will be spaced from 12 to 40 feet apart and may be bolted together to create lengths well in excess of 100 feet.

Wooden purlins are installed with metal hangers on 8-foot centers. The common size of purlins is 4 X 12 inches with the length depending on the spacing between beams. Joists measuring 2 X 4 inches X 8 feet are installed with metal hangers on 2-foot centers between the purlins and run parallel to the beams. Sheets of plywood (4 X 8 feet X 1/2 inch) are nailed over this framework. The plywood is then covered with composition roofing material. A three-layer insulation paper is stapled to the underside of the roof between the beams and purlins. This paper offers little protection to the 2 X 4 inch joists and 1/2 inch sheets of plywood. Insulation paper consists of tar impregnated kraft paper covered on either side by thin aluminum foil.


ROOFING MATERIAL
4 X 8
PLYWOOD

Strengths: The strengths of this roof are beams, purlins and the perimeter of building where roof ties into the exterior walls.

Hazards: Span supports for beams 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. When the insulation paper is subjected to fire, the foil will peel away from the middle layer of tar-impregnated paper. This paper will then begin to give off flammable gases that build up between the insulation paper and plywood decking. When ignition temperature is reached, the gases will flash resulting in heavy char to the wood and burning insulation dropping to the floor below. Fire is then able to expose the 2 X 4-inch joists and 1/2-inch plywood decking which offer little resistance to fire.

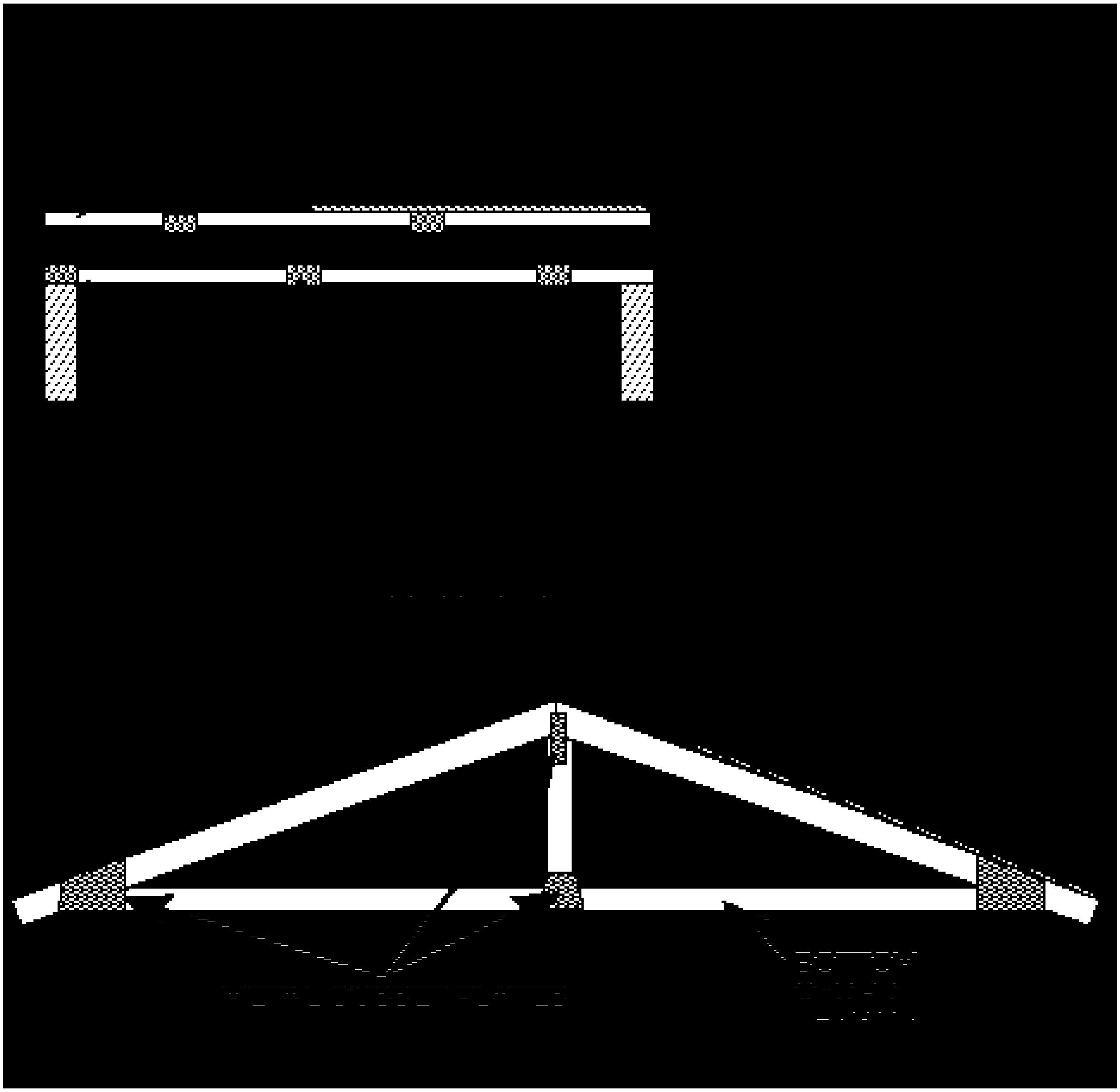
When walking across a panelized roof, utilize the beams or purlins. Any other section of this roof is comprised of 2 X 4's and 1/2-inch plywood that will rapidly fail when exposed to fire.

Metal Gusset Plate Trusses

Description: Rough carpentry wood trusses used in commercial and residential applications utilize 2 X 4's held together by metal gusset plate connectors (See illustration next page). This truss system is enjoying widespread use in roof, floor, rough window, and rough door openings. Trusses for roofs are constructed in a wide variety of forms. Regardless of form, these trusses share common features. Trusses are constructed of top chords, bottom chords, and webbing (supports between the top and bottom chords are referred to as "webbing"). Metal gusset plate connectors hold the trusses together. Metal gusset plate connectors vary in size, thickness, and depth of penetration; however, 18 gauge steel plates with prongs that produce 3/8-inch penetration are common and used in a wide variety of applications.

Utilizing 2 X 4's, spans of up to 55 feet will be found. A point of interest with this type of construction (also open web construction and wooden "I" beams) is the fact that trusses are supported at their outside edges only (unless used as a cantilever truss). Interior partition walls do not support the truss at any point along the bottom chord. Eighteen gauge "roof truss clips" may be found at various chords. These clips are nailed to the bottom chord and to the top plate of the interior wall. Roof truss clips provide some lateral stability for partition walls. In this configuration, interior partition walls could be classified as "free standing."

Common on-center spacing for this construction is 2 feet and may be covered with 1/2-inch plywood. This method of construction is used in floor and roof systems.



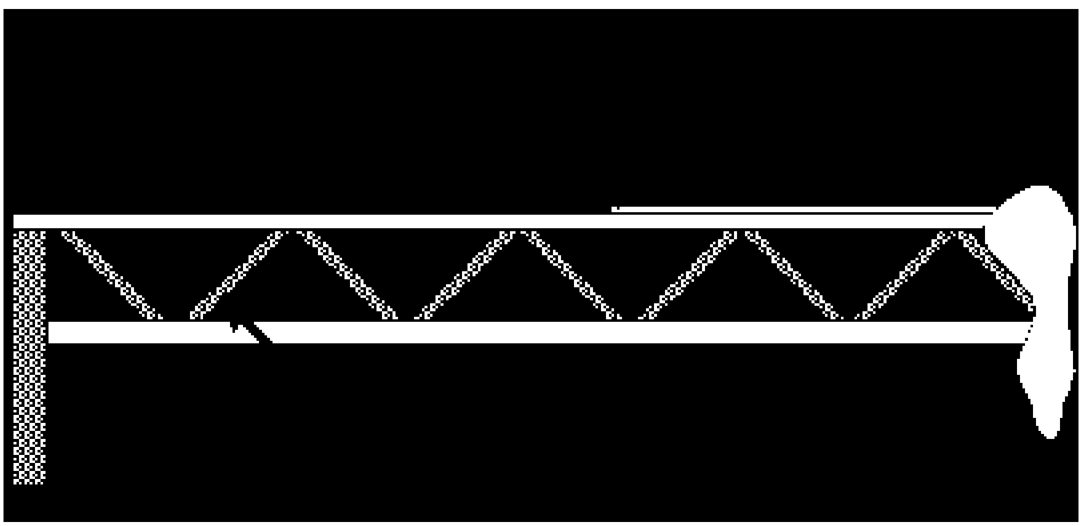
Strengths: Consider the area where the trusses cross or are tied into the outside bearing walls as strong areas.

Hazards: Extensive use of 2 X 4-inch trusses with metal gusset plate connectors equals short burning time and early failure and collapse. These trusses are under tension and compression and when the bottom chord or webbing fails, either from connector plates that have pulled out or from deep char, the truss will fail. When the metal connector plates and surrounding wood are exposed to fire, the plates will fail in a short period of time by pulling out of the wood. The bottom chord of the truss has replaced the 2 X 6-inch or larger ceiling joist of conventional construction. Coupled with the fact that these bottom chords do not rest on the interior walls, which offer additional support, expect total collapse of portions or the entire roof in a short period of time. As in other truss-type construction, depth of cuts for ventilation purposes is critical so as not to reduce the structural integrity.

An additional hazard is identification of the construction of the roof you are about to ventilate. A simple flat roof may be constructed from different types of joists or trusses, yet there is a wide range of strength factors inherent in different types of construction.

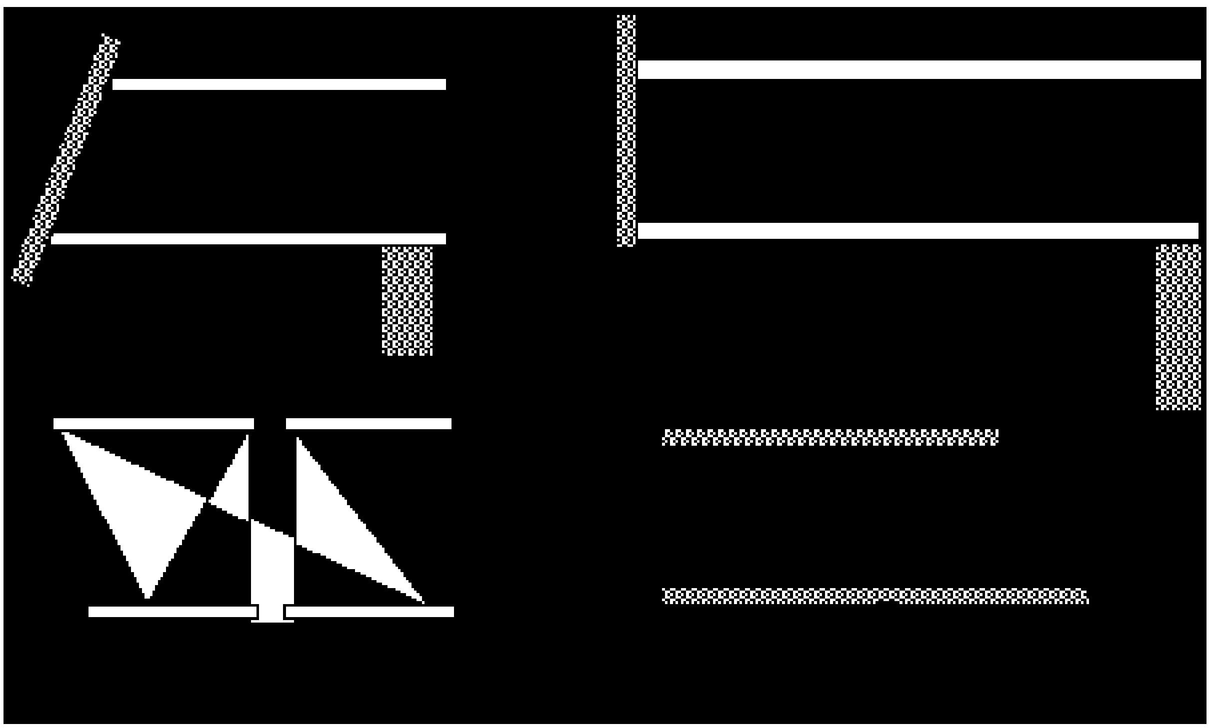
Open Web Construction (Trussed Joist Construction)

Description: Open web construction consists of bottom and top parallel wooden supporting beams called chords that are cross-connected by steel tube web members. The top chord (supported) and under-load offer a bridging effect causing the top chord member to be in compression and the bottom chord member (unsupported) to be in tension. Open web construction is prefabricated at the factory before installation with either parallel chords laid on edge or with flat laid chords. The steel tube web members are prefabricated from 1 to 2-inch cold rolled steel tubing with the ends pressed flat into a semicircular shape and a hole punched through each end. These flattened ends are then inserted into slots in the chords. Steel pins (up to 1 inch) are then driven through the chord members and through each end. These flattened ends are then inserted into slots in the chords. Steel pins (up to 1 inch) are then driven through the flattened ends of the web members completing the assembly. When the prefabricated joists are installed, top chord members are secured to the top of bearing walls with bottom chord members remaining unsupported away from the wall. Spans to 70 feet are possible using a single 2 X 4 or two 2 X 3's as top and bottom chord members. Two-by-fours exceeding lengths of 20 feet are made possible by joining different lengths of 2 X 4's in glued mitered "finger joints". Normal on-center spacing is 2 feet. This method of construction is used in floor and roof systems.



Strengths: Consider the perimeter of the building where the roof ties into the exterior wall as a strong area.

Hazards: The hazards, of this roof are many. Basically, this roof is constructed of 2 X 4's or 2 X 3's under tension and compression and 1/2-inch plywood decking. These components offer minimum resistance to fire. Some structures leave the chords exposed to the interior of the structure, which increases the exposure hazard and assists in larger areas of the roof being exposed to fire. Expect to find a lack of fire stops in this construction. Due to the size of lumber and chord members in tension and compression, expect rapid failure of this construction. When 2 X 4's are laid flat as chords (1 1/2-inch thick) with 1/2-inch plywood decking, fire fighters only have to cut 2 inches deep (when cutting for ventilation purposes) to cut through the chord members. This may cause partial roof failure of the area supported by the severed chords.



Shown above are typical bearing conditions one might encounter with truss construction. Note how some extend well past the bearing wall. If a fire were to burn through the truss on the inside, the remainder of the truss could topple over. Beware of this situation!

Truss joists are lighter in weight than most other systems. This feature cuts erection costs, speeds construction and makes possible the use of less costly footings, foundations and bearing walls. For these reasons, truss construction is very popular in commercial areas. A truss may span up to 25 feet in most floor systems and up to 40 feet in many roofs. Multiple spans are possible up to 70 feet total length.

Wooden "I" Beams

Description: Consists of three main components:

1. Top Chord
2. Bottom chord
3. 3/8-inch plywood stem

The stem is joined to the top and bottom chords by a continuous glued edge joint. Two by fours are used as chords, but 2 X 3-inch chords are very common. Some chords may resemble plywood because of laminations. However, the laminations (trade name of Micro Lam) or veneers run horizontally in the chords. Micro Lam differs from plywood where every other veneer is 90x to the preceding veneer. The Micro Lam veneers are stronger than solid sawn lumber. In the 2 X 3-inch configuration, spans of up to 40 feet will be found. Until adequately braced and the plywood decking is nailed down, this construction is very unstable. Common on-center spacing for this construction is 2 feet. Half-inch plywood is utilized for the decking. Used in floor and roof systems.

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

Hazards: The material there is to burn consists of a 3/8-inch plywood stem and 2 X 3 or 2 X 4 inch chords. It will take little time for the 3/8" plywood to burn, weaken and cause collapse of the chords and the roof or floor. Buildings will be found with open and unprotected chords. Common practice is to run heating and air conditioning ducting of various sizes through the stems, which removes a good percentage of the stem and gives fire horizontal access to adjacent "I" beams. As with other lightweight roofs, depth of cuts for ventilation purposes is critical.

STRUCTURAL COLLAPSE

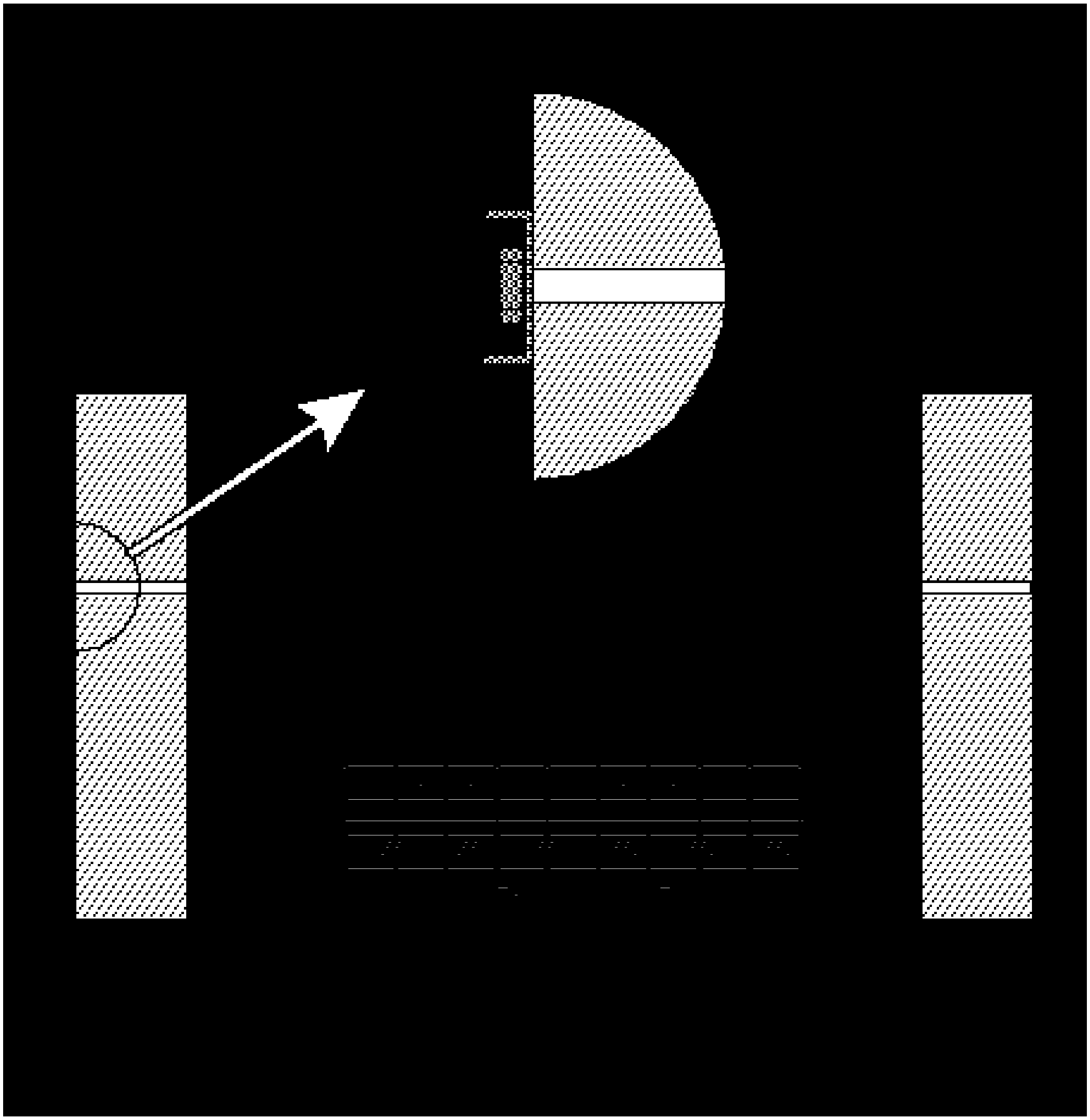
There are many causes of structural collapse in buildings. Failures can result from architectural faults in the original construction, the age of the building, slip-shod repairs, and heavily laden floors. Fire fighters must be able to identify the indications of potential and imminent collapse to ensure the safety of both themselves and others at an incident.

Design Faults in Construction The worst potential fault in building construction is unprotected vertical shafts and openings. This includes stair shafts, vents, pipe chases and atriums. These open shafts are dangerous because they expose other floors of the building to fire and smoke. In the case of vents, a chimney effect can result fueling the fire and spreading smoke. Combustion products can sweep up from the original fire and involve other areas of the building. This fault is responsible for the greatest loss of life not only because people can be overcome with smoke but also because exits form the building are inaccessible.

Large unprotected floor areas are also responsible for building collapse under fire conditions. Floors without physical barriers can become completely engulfed by fire. Because there is nothing to stop the progress of fire, a draft effect is created moving the fire across the floor. When a floor becomes enveloped in flame, fire fighters find it difficult to fight the fire due to intense heat. Fire fighting under these circumstances is accomplished through halls, doors, and windows and in the case of very large floors, the fire will be extremely difficult to contain because the fire hose stream cannot reach the center of the floor.

Building collapse can result from the high temperatures that unprotected metal structures may endure during a fire. Steel is used frequently in building construction for reasons of strength, elasticity and cost. The problem arises when the metal is subjected to temperatures of over 1,000 degrees. The steel will expand and possibly disrupt other structural components. Under even higher temperatures, the metal can fail completely. Firefighters should be aware, that when comparing steel and wood where the structural members are of equal strength, a wooden support will resist fire much better than a steel support. Large wooden members will burn slowly and resist fire for longer periods of time than unprotected steel, which has a poor record of withstanding fire.

Other faults that point to the possible collapse of buildings are alterations of structural supports, bracing old supports with steel rods (i.e. look for "stars" on the outside of the building), steel angle iron used to reinforce the walls, and overly laden floors. Such alterations eliminate, or cheaply substitute structural supports to gain more usable room or to save money.



<u>Old Buildings</u> The major problem with older buildings is deterioration. Mortar and brick structures tend to deteriorate over time and fire fighters should be wary of this problem. This situation can sometimes be observed via obvious cracks in masonry walls. As well, fire fighters should look for clean or new wood at the joist ends as an indication of shrinking. When the wood I-beams age, they dry out and shrink and under heavy loads may sag and the new looking wood is indicative of this. Often the older I-beams have been reinforced with steel rods. If a wall has been reinforced in this manner, "stars" may be present on the outer walls to hide the rods. The stars are basically nuts that screw on the end of the rods helping to support the structure.

Imminent Contributors to Collapse During fire operations, fire fighters may observe events that could lead to collapse of the structure. For example, lack of water drainage on the floor greatly increases the risk of collapse. Two inches of water on a floor 40 X 80 feet would add more than 15 tons of weight to the floor. Note - a 250 GPM nozzle can put out a ton of water each minute.

The following list of events should serve as warnings of imminent building collapse and fire fighters observing any of these during fire operations must leave the building and report to his/her Captain.

a. Ankle deep water on the floor.
b. As a general rule, a large fire that has been out of control for 13 minutes or more. Studies have shown wood truss construction to fail at this point.
c. Steel beams, columns and posts that have been exposed to 1,000-degree Fahrenheit heat may fail. d. Unsupported walls.
e. Sagging or bulging floors and walls.
f. Rising dust indicating movement of the building, floor, or roof.
g. Holes in the floor.
h. Spongy floors or roof.
i. Cracks in the walls, floors, or roof.
j. Smoke and/or water leaking through the walls.
k. Burned out trusses or I-beams.
l. Sliding sheets of plaster.
m. Walls or columns out of plumb (square).
n. Interior explosions, rumblings, noises, or heavy gusts of smoke.
o. Steel beams elongating due to the heat of the fire and pushing out walls.

Hazards Which May Cause Structural Collapse Fire fighters should be aware of the potential hazards which may cause the structure to collapse under stressful conditions.

a. Cutting holes in the floor for irrigation may cut the structural supports if caution is not exercised.
b. Do not stand near or under marquees or large signs as they are usually unsupported and may fall quite easily.
c. Buildings that vibrate due to blasting, construction, or machinery are more susceptible to early collapse during a fire.
d. Severe weather conditions can weaken an old building.
e. Watch for large tanks of flammable materials.
f. Watch for large signs, water tanks, HVAC equipment or other extraneous weights on the roof of the building.
g. Avoid standing under large ornamental roofs and chandeliers. Under fire conditions, these unsupported structures can fall.
h. Do not stand in the middle of a room; remain at or near a supporting wall. The center of the floor is usually the least supported part of a buildings framework and will provide less stability than the portion of the floor near a supporting wall.

i. Beware of unsupported cantilevered sidewalk coverings and Mansard roofs commonly found at strip malls. These structures provide a concealed area for fire to spread unchecked and may fail without warning.

BUILDING CLASSIFICATION

Five major building types are identified by the building industry. These classifications are based on the materials used in the construction and the hourly fire-resistance rating of the structural components. Construction continues to differ in design, building method, roof types, and materials utilized and each structure will pose unique challenges to the fire fighter.

The classification system for types of building construction considers only the materials involved in the construction. For example, the exterior walls, roof, structural frame, and shaft enclosures play a major role in deciding the type of construction and its fire resistant rating. The classification does not consider the occupancy type or use of the building. A building may contain the same features as another building and still be considered a different type structure to the other building. The features that are not considered in the building classification system include but are not limited to exterior exposure, location, occupancy, mechanical damage to fire protective material, and construction of interior walls. These, however, need to be accounted for in the overall fire safety design. For more information on building types, fire fighters should refer to the California Building Code.

Type I, Fire Resistive Construction A structure classified as a Type I construction will have the ability to withstand fire and any resulting damages much better than any other class. The Type I construction is commonly referred to as “fire resistive”. Most high rises are Type I construction. Structural members that are rated to be fire resistive characterize this class. Only noncombustible, or in some cases limited combustible, materials are permitted in fire resistive construction. Fire resistive material is defined as material that when subjected to fire or heat will not ignite, burn, support combustion, or release flammable vapors. Limited combustible material is defined as material that has a potential heat value not to exceed 3,500 BTU per pound. In contrast to this, pine sawdust releases over 9,600 BTU per pound.

Fire fighters must recognize that fire resistive construction does not necessarily prevent loss of life or property damage during a fire. This type of structure will not fuel the fire and usually the chance of collapse is small. However, there are many documented cases of extensive interior damage and high loss of life from fire that did not structurally damage the Type 1 building but burned the contents within it.

Type II, Construction A structure classified as Type II construction is commonly referred to as “noncombustible construction”. The main structural components are noncombustible but may have no fire resistance. Typically, this type of construction can be fire resistive, 1 hr. or no general requirement (i.e., constructed of metal frames, metal clad, concrete, steel, iron or masonry). In addition, unprotected steel framing a wide variety of assemblies are used to conform to this type of construction. Refer to California Building Code for additional information.

The key to this type of construction is that the structural supports do not contribute to the fire. Under fire conditions, unprotected structural steel may sag and then collapse due to heat. Collapse should be expected after 13 minutes of a well-developed fire, when steel supports begin to sag or when a column has become seriously weakened.

This class of construction is utilized where expected fire severity is minimal or in conjunction with fire suppression methods such as sprinkler systems. Usually, these structures are pre-designed, economical buildings.

Type III, Ordinary Construction A structure classified as a Type III construction is commonly referred to as "ordinary construction". The bearing walls of this type of construction must have a minimum fire resistance rating of one hour. Both nonbearing and bearing walls are constructed of non-combustible materials while roofs, floors, and interior framing are constructed mainly out of wood that is smaller in dimension than that required for Type IV structures.

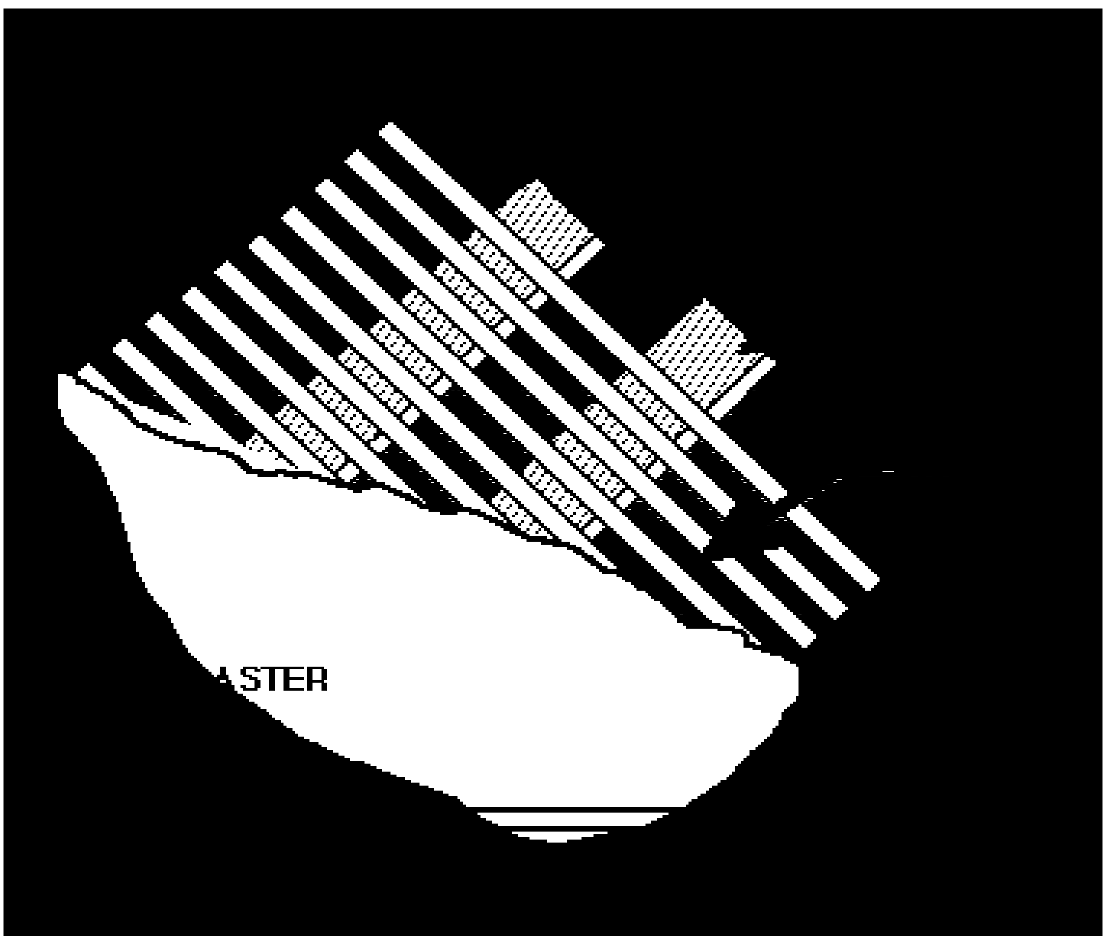
Type III construction is widely utilized and is often referred to as "brick, wood-joisted", or "brick joist" construction. The term "open joist" is defined as open or exposed interior combustible structural members. The main difference between Type III and Type IV construction is the dimensions of the supporting wood members. Another significant difference is that Type III ordinary construction may contain combustible concealed spaces that are created between floor and ceiling joists and between the studs in partition walls when they are covered with interior finish materials. These spaces provide a combustible path for the spread of fire throughout the building unless fire-stopping safeguards are utilized. This type of structure contains all the hazards associated with combustible wood buildings and few advantages to fire fighters.

Type IV, Heavy Timber Construction A structure classified as a Type IV construction is commonly referred to as "heavy timber construction". Like Type III construction, the exterior walls are normally of masonry construction and the interior structural members are combustible. Two significant distinctions exist between Type III and Type IV construction. First, in Type IV construction the beams, columns, floors, and roofs are made of solid or laminated wood with dimensions greater than in Type III construction. Second, in type IV construction concealed spaces are not permitted between structural members.

Generally, the columns beams, and girders are constructed of heavy timber, however, other materials may replace wood members if they are the same dimensions and have a fire resistance rating of at least one hour. A heavy timber rating requires that all columns be at least 8 X 8 inches and beams and girders at least 6 X 10 inches. Wood floors are commonly 3-inch tongue and groove or 4-inch laminated wood. Roofs are typically 2-inch tongue and groove or 3-inch laminated wood structures. All interior partitions enclosing stairways and other openings through floors must be designed to have a fire resistance rating of at least one hour.

The weakest points to consider in this type of construction during fire conditions are the edges, joints, and connections of timber members. It is generally accepted, however, that true heavy timber (Type IV) construction will withstand fire better than unprotected noncombustible structures.

<u>Type V, Wood Frame Construction</u> A structure classified as a Type V construction is commonly referred to as "wood frame construction". This construction class is defined as structures in which the exterior walls, bearing walls, partitions, floors, and roofs are either wholly or partly wood or some other combustible material. This class will not conform to either Type III or Type IV construction but can be considered protected if floors and roofs have a one hour fire resistance and stability rating. To be made reasonably safe, proper attention must be given to fire protection systems, protection against exposure fires, and protection against spreading fires (e.g. in sheathed areas). Refer to page 4 of this chapter for a schematic of "wood frame construction". For more information, fire fighters should refer to the current California Building Code.



BUILDING INTERIORS

There are three principal elements that determine the overall fire resistance of a building: the fire resistance of the building (construction type), contents or production processes within the building (occupancy), and the characteristics of the interior finish on the building. The interior finishes include but are not limited to wood, plywood, plywood paneling, plaster, gypsum wallboard, fibrous ceiling tiles, plastics, and a variety of wall coverings. Surface coatings may also exist such as paint, varnish, and acoustic spray that will add to fire characteristics. Interior finishes can affect a fire in four ways:

a. They may influence the rate at which the fire build up reaches "flashover".
b. They can contribute to fire extension by allowing the flame to spread over its surface.
c. They may add to the intensity of the fire by contributing additional fuel.
d. They can add toxic gas and smoke that will contribute to life and property hazards.

Once a fire has gained some headway, the upper portion (ceiling) will become extremely hot as the gases fill it. If this area becomes hot enough, the gases may ignite. This is commonly referred to as "Flashover". Thermal radiation transpires from the combustion heating the materials in the area rapidly. When the combustible materials have become heated to their ignition temperatures, simultaneous ignition will occur. An interior finish that absorbs and holds heat would be more preferable because it would inhibit flashover for a longer period of time.

Many burning interiors are dangerous not only because of the heat factor but also due to the smoke and toxic gases they release. In fact, fire tests have shown a greater threat to life because of toxicity and smoke inhalation. Fire fighters should use extreme caution when fighting interior fires so they and others are not overwhelmed by toxic gas or smoke.

Ideally, the best interior will be made of relatively thick noncombustible material. The material will be able to withstand very high temperatures, inhibit flashover, would not add fuel to the fire, will not allow fire to spread over its surface to other materials and will not produce smoke or toxic gas. Such materials include firewalls, doors, fire exits and escapes, windows, and noncombustible (fire) partitions.

STRUCTURAL FEATURES INFLUENCING FIRE SPREAD

In a study carried out by the NFPA, it was found that inferior construction, unprotected openings, large open areas, and inoperative fire doors were major determinants in the amount of damage done to a structure and its interior in fire conditions. These features were found to contribute to the spread of fire. Furthermore, it was determined the speed of flame spread over a substance is directly influenced by the amount of flammable vapors released by combustible materials when they are heated, their texture, and thickness. The following structural features will help limit the spread of fire if they are constructed properly as defined in the California Building Code). For more information on these features and other less common ones, refer to the current California Building Code.

Fire Walls Fire walls are typically constructed out of concrete, structural clay tiles, or some other structurally sound and noncombustible material and must have a fire resistive rating of at least one hour. Furthermore, firewalls must be able to remain intact if and when there is collapse on either side. A firewall will be continuous from the foundation to a parapet above the roofline of the building. The height of the parapet portion is dictated to be at least 30 inches above the roofline. In addition, these walls must have a minimum thickness dictated by the type of construction (the California Building Code). All firewalls must have parapets, wing walls, be attached to the foundation, and have fire resistive ratings as required by location, type of construction, and occupancy. Openings in firewalls must conform to the requirements of the building type and the requirements set forth in the California Building Code.

Some of the code violations fire fighters may encounter when dealing with fire walls include: Inferior construction materials, lack of thickness in the wall, no parapets, and openings that are not correctly constructed, inoperative, or blocked open. Fire fighters should always inspect firewalls during prefire planning and inspections to determine aspects of deterioration and imperfections that may create hazards during a fire.

Fire Partitions Fire partitions are installed as a resistance to fire spread, but are not considered a firewall. They are constructed of noncombustible or protected combustible materials and are attached or supported by structural components having a fire resistant rating equal to or better than the fire partition (usually one to two hours). As with firewalls, openings must conform to the requirements set forth to provide adequate fire protection. The fire resistance of a fire partition will be governed by the type of construction used in the building.

Fire Doors Typically, fire doors are used for protection of both vertical and horizontal openings. Fire doors can be horizontal or vertical sliding, single or double swinging, or overhead rolling. The most frequently used fire door is the horizontal sliding door. Any of these door types may or may not be counterbalanced. Often, fire doors are either self closing or automated. Self-closing doors will return to a closed position after opening. Automated doors may remain open after opening them, but will close when heat or smoke actuates the closing mechanism. Fire doors must not be locked though they may be latched. In addition, these doors should never be blocked, wedged or in a state that would prevent them from closing. Automatic closing doors must be kept in proper working order at all times. Fire doors can be considered safe if they contain a current label from the "Underwriters Laboratories" or "Factory Mutual Laboratories" as evidence of testing. For more information refer to NFPA Standard # 80.

Fire Windows and Fire Shutters For these types of enclosures to be effective in containing fire spread, they must be properly maintained and serviced. Often these openings are associated with exterior wall openings.
There are locations where fire windows are covered by shutters (i.e. at three, one, and 11/2 hour openings). The shutters must carry a rating equal to or greater than the wall opening they are protecting. These fire shutters must either remain closed or must close automatically under fire conditions. Once closed, fire shutters must remain secure to be considered effective in reducing fire spread. Of the different types of fire shutters, the automatic rolling shutters installed over windows on the interior sides of the building are considered the most useful and practical.

Curtain Boards (Draft Curtains) Curtain boards are most generally found in large open areas of buildings. Their major purpose is to direct fire and smoke into a pre-designed area for rapid ventilation. At the same time, they are designed to prohibit flame and smoke spread in other directions. This is especially useful in sprinklered buildings to avoid water damage to unaffected areas. The operation of sprinklers can be localized to the fire area. For these fire resistive structures to be considered effective, they cannot be spaced more than 250 feet apart for low and moderately heated occupancies. In buildings that are subject to high heat sources, curtain boards must not be spaced any further than 100 feet apart. The depth of a curtain board must be a minimum of six feet but in some cases (under severe fire hazards) may be doubled or as close as 8 feet from the floor.

Ventilation Devices These systems are designed to complement other fire safeguards and are not replacements for fire protection devices. Vents are very useful in smoke and heat dissipation, especially in buildings where vapors and dusts are highly combustible. For a venting system to be considered effective, it should be free of any human element. Rather, it should be automatic using fusible links, hinged dampers, and counterweights that are heat reactive. Types of vents include: monitor controlled, continuous gravity, unit type, sawtooth roof skylights, and exterior wall openings.
Monitors usually make use of a fusible links that are effective from as low as 165 degrees F to 212 degrees F or higher if so required. The fusible links operate vent doors that may be glass, metal panels, or louvered when heat containment is not a factor.

Continuous gravity vents are narrow slot openings that are attached to weather hoods on the roof. Many will have movable shutters, which will open automatically in the event of a fire. This style of vent is most common in buildings where high heat production is of concern.

Unit type vents are light weight metal frames or housing with built-in shutters that open in the event of high heat or fire (e.g. fusible links). This type of structure is most commonly associated with curtain boards.

Sawtooth roof skylights are sashes of glass usually non-wired that can be opened to form a vent. Often this style of venting device must be operated manually and is influenced by wind direction and force.

Exterior wall openings are most effective in structures where heat and smoke do not have to travel more than 60 feet. They are usually characterized by louvered, open vents but can also remain closed and automatically open in the event of fire.

Fire Exits and Escapes Buildings and structures must have appropriate fire escapes and exits in accordance with the location, size, occupancy, type of construction, and fire protection available. Fire escapes and exits must be correctly marked, lighted in dark atmospheres, and prove the most accessible route to safety. Furthermore, they cannot be obstructed in any way that would prohibit a swift evacuation of the occupants. . Exit doors shall be openable from the inside without the use of a key or any special knowledge or special effort. For more information on fire escapes and exits fire fighters should refer to NFPA 101, the Life Safety Code, and California Building Code.

Fire and Smoke Dampers These are used to restrict fire and smoke to the involved area and away from unaffected areas. Fire and smoke dampers operate much like venting devices but in the opposite manner: Instead of allowing smoke to dissipate these devices will close under fire conditions. Like automatic vents many are controlled by fusible links, heat actuating switches, and in some cases, smoke detectors.

Fire dampers are generally automated and once closed, will remain closed until manually opened. These devices are required in number of circumstances, which include:

a. Where a duct passes through a fire protected wall or partition or roof.
b. At fresh air intakes.
c. At branches in the main duct.
d. Vertical ducts pass through fire resistive floors.
e. When ducts have openings installed in a fire resistive ceiling.

There are other circumstances where fire dampers will be required and a number of exceptions that pertain to particular situations. For more information on fire dampers, fire fighters should refer to NFPA and the California Building Code.

Smoke dampers are commonly required in air conditioning systems and are intended to interrupt the flow of air or smoke through the system when the air conditioner is shut down.

Fire Stops Fire stops are utilized to prevent fire spread within the hollow walls, floors, and other internally open areas in a building or structure. They are usually pieces of wood (2 X 4 inch) that are placed between wall studs, partitions, ceiling planks, etc., to cut off any draft within the hollow areas. When fire stops are not used its probable that a fire could rage through the structure, burning unexposed internal areas before it is ever discovered. The minimum fire stopping would include isolation of all hollow walls at the floors and ceilings, isolation of the ceilings at the walls and curtain boards. For more information on fire stopping refer to California Building Code.