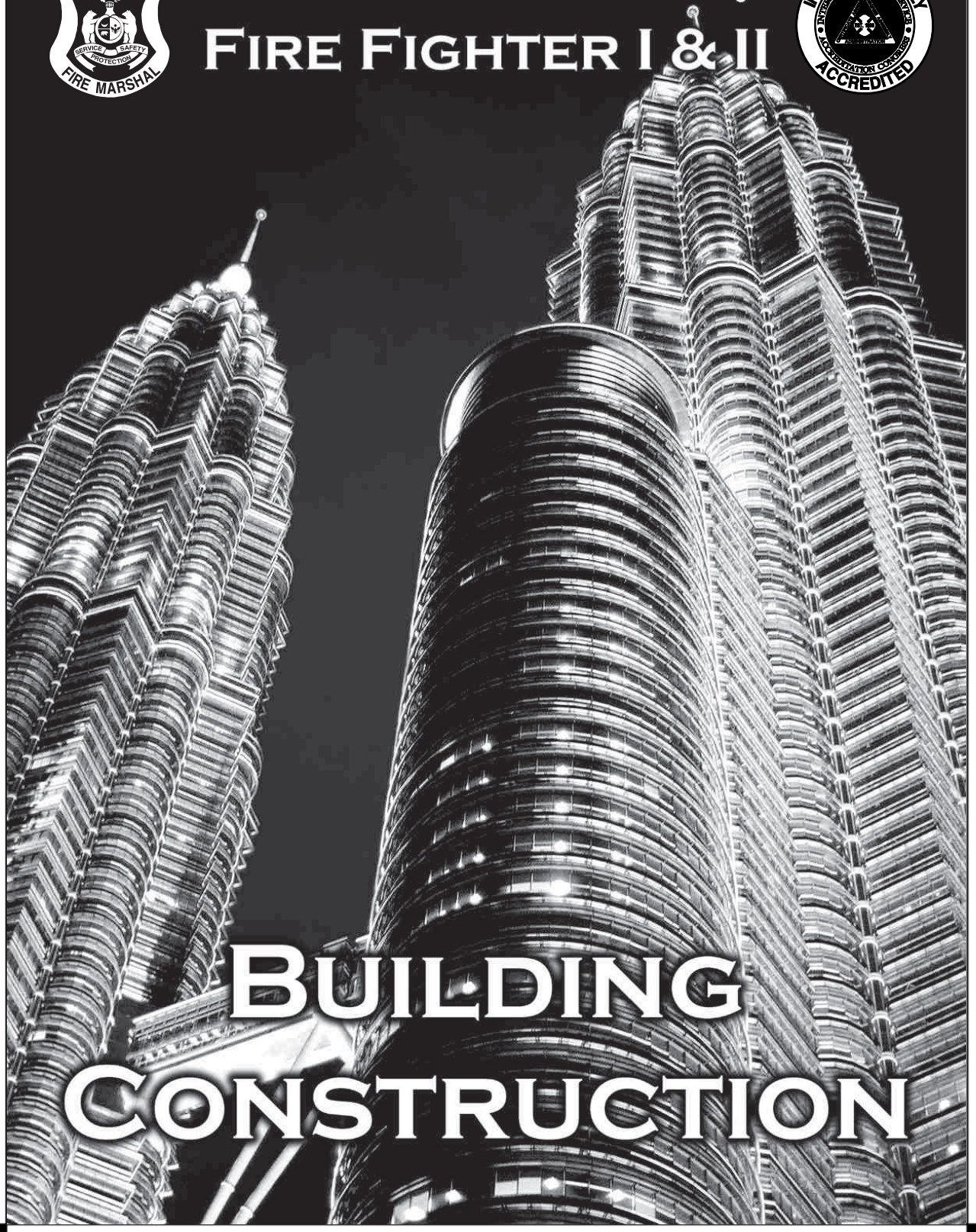
Missouri Division of Fire Safety

Fire Fighter I & II



Building Construction

UNIT OBJECTIVES

Upon completion of this unit of study, the student should be able to:

1. Define terms related to building construction.
2. Define the basic structural characteristics of the five types of building construction and describe the general fire behavior expected with each.
3. Explain dangerous building conditions including indicators of possible building collapse caused by fire and fire suppression activities.
4. Identify the hazards that can be expected with truss lightweight construction.
5. Explain how fire and fire suppression activities affect different types of building materials.

NFPA STANDARDS

Successful completion of the information in this section is necessary to fulfill the requirements of the following sections of NFPA 1001-2008:

Fire Fighter I Standard

5.3.10* Attack an interior structure fire operating as a member of a team, given an attack line, ladders when needed, personal protective equipment, tools, and an assignment, so that team integrity is maintained, the attack line is deployed for advancement, ladders are correctly placed when used, access is gained into the fire area, effective water application practices are used, the fire is approached correctly, attack techniques facilitate suppression given the level of the fire, hidden fires are located and controlled, the correct body posture is maintained, hazards are recognized and managed, and the fire is brought under control.
(A) Requisite Knowledge. Principles of fire streams; types, design, operation, nozzle pressure effects, and flow capabilities of nozzles; precautions to be followed when effects of construction type and elapsed time under fire conditions on structural integrity; and the advantages and disadvantages of vertical and trench/strip ventilation.
(B) Requisite Skills. The ability to transport and operate ventilation tools and equipment; hoist ventilation tools to a roof; cut roofing and flooring materials to vent flat roofs, pitched roofs, and basements; sound a roof for integrity; clear an opening with hand tools; select, carry, deploy, and secure ground ladders for ventilation activities; deploy roof ladders on pitched roofs while secured to a ground ladder; and carry ventilation-related tools and equipment while ascending and descending ladders.

5.3.12 Perform vertical ventilation on a structure as part of a team, given an assignment, personal protective equipment, ground and roof ladders, and tools, so that ladders are positioned for ventilation, a specified opening is created, all ventilation barriers are removed, structural integrity is not compromised, products of combustion are released from the structure, and the team retreats from the area when ventilation is accomplished.
(A) Requisite Knowledge. The methods of heat transfer; the principles of thermal layering within a structure on fire; the techniques and safety precautions for venting flat roofs, pitched roofs, and basements; basic indicators of potential collapse or roof failure; the effects of construction type and elapsed time under fire conditions on structural integrity; and the advantages and disadvantages of vertical and trench/strip ventilation.
(B) Requisite Skills. The ability to transport and operate ventilation tools and equipment; hoist ventilation tools to a roof; cut roofing and flooring materials to vent flat roofs, pitched roofs, and basements; sound a roof for integrity; clear an opening with hand tools; select, carry, deploy, and secure ground ladders for ventilation activities; deploy roof ladders on

NFPA STANDARDS

pitched roofs while secured to a ground ladder; and carry ventilation-related tools and equipment while ascending and descending ladders.

Fire Fighter II Standard

6.3.2* Coordinate an interior attack line for a team's accomplishment of an assignment in a structure fire, given attack lines, personnel, personal protective equipment, and tools, so that crew integrity is established; attack techniques are selected for the given level of the fire (e.g., attic, grade level, upper levels, or basement); attack techniques are communicated to the attack teams; constant team coordination is maintained; fire growth and development is continuously evaluated; search, rescue, and ventilation requirements are communicated or managed; hazards are reported to the attack teams; and incident command is apprised of changing conditions.

(A) Requisite Knowledge. Selection of the nozzle and hose for fire attack, given different fire situations; selection of adapters and appliances to be used for specific fireground situations; dangerous building conditions created by fire and fire suppression activities; indicators of building collapse; the effects of fire and fire suppression activities on wood, masonry (brick, block, stone), cast iron, steel, reinforced concrete, gypsum wallboard, glass, and plaster on lath; search and rescue and ventilation procedures; indicators of structural instability; suppression approaches and practices for various types of structural fires; and the association between specific tools and special forcible entry needs.

(B) Requisite Skills. The ability to assemble a team, choose attack techniques for various levels of a fire (e.g., attic, grade level, upper levels, or basement), evaluate and forecast a fire's growth and development, select tools for forcible entry, incorporate search and rescue procedures and ventilation procedures in the completion of the attack team efforts, and determine developing hazardous building or fire conditions.

NOTES	STUDENT GUIDE
	I. Building Construction and Fire Fighting A. An understanding of the types of building construction can assist the fire fighter in knowing how fire is likely to spread or extend throughout a given construction 1. Building construction can help give fire fighters some sense of predictability as to the fire's path, and how best to fight it 2. Some construction types resist attack by fire much longer than others 3. Other construction types can contribute to the severity of a fire B. Any fire can compromise a structure's integrity by weakening the entire system of supports designed to keep a building standing 1. Fire fighters who are unfamiliar with the techniques of determining weakened construction may unknowingly put themselves in a dangerous situation **II. Building Construction Terms** *(Essentials p. 138)* A. Balloon frame: wood frame construction in which exterior wall studs extend from the basement or foundation to the roof, allows fire to extend undetected between levels B. Beam: C. Bowstring truss: a roof assembly with a curved (arched) top chord and a horizontal bottom cord

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	D. Cantilever: a beam unsupported at one end, used to support balconies E. Column: F. Dead load: the load on a structure due to its own weight and other fixed weights G. Fire door: a fire resistive rated assembly consisting of a solid-core door, door frame, and hardware, required to protect opening in firewalls and used to confine fire to one area H. Fire wall: I. Girder: a horizontal structural member used to support beams and joists J. Gypsum board: interior finish wall material consisting of gypsum, starch, water, and other additives between treated sheets of paper; also referred to as drywall and sheetrock K. Joist: L. Live load: all furniture, people, or other movable loads not included as a permanent part of the structure M. Load bearing: a structural member that carries part of the load of the structure (roof, floors, etc.) in addition to its own weight N. Partition wall: an interior wall dividing areas of the structure, may or may not be load-bearing

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	O. Party wall: a fire wall used for joint service between two buildings P. Plate: the top or bottom horizontal structural member of a frame wall Q. Platform construction: Frame-type construction in which each floor interrupts exterior wall studs forming a fire barrier at each floor R. Rafter: S. Rated assembly: two or more construction components forming an assembly with a specific fire-resistance rating T. Stud: U. Truss: a wooden or metal structural assembly made up of one or more triangles in a flat plane **III. Common Building Materials** *(Essentials p. 141)* A. Wood - most common building material used in the U.S. 1. Used in load-bearing and non-load-bearing walls 2. Ignition of wood depends on the size of the wood and its moisture content a. Smaller wood members ignite faster, losing their strength b. Wood with a high moisture content does not ignite as quickly as kiln-dried wood

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	3. Newer construction techniques may contain composite materials a. Made of wood fibers, plastics and other materials joined by glue or resin b. Plywood, particleboard, fiberboard, and paneling c. May be highly combustible and produce toxic gases or rapidly deteriorate in a fire B. Masonry 1. Includes bricks, stones, and concrete blocks 2. 3. Concrete walls may be load-bearing 4. Brick and stone walls may be veneer walls a. Veneer walls are decorative and attached to exterior load-bearing walls b. 5. Masonry can be affected by fire a. Concrete blocks may crack b. Bricks may not show any loss of integrity c. Mortars between bricks and blocks can be degraded by heat and weakened d. Rapid cooling by water may cause masonry materials to crack

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	6. Masonry walls can become weakened over time a. Exposure to weather b. Settling of the ground C. Cast iron 1. Cast iron is usually found in older buildings 2. Was used as exterior surface coverings and bay windows 3. 4. The major concern for fire fighters is that the bolts and connections holding cast iron can fail in a fire causing large cast iron sections to collapse D. Steel 1. Used for structural support in large buildings 2. Steel structural members can elongate when heated a. Can cause collapse of exterior load-bearing walls b. If restrained at the ends, it buckles and fails in the middle c. 3. Fire fighters should be aware of how long steel members have been exposed to fire

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	E. Reinforced concrete 1. Concrete is internally reinforced with steel bar (rebar) or wire mesh 2. Performs well in fire conditions a. Can lose strength when concrete spalls and cracks from heat b. Heat can cause the bond to fail between the concrete and steel reinforcement 3. Fire fighters should check for cracks and spalling of concrete surfaces indicating the concrete has weakened F. Gypsum 1. Plaster and wallboards are constructed from gypsum 2. Has a high water content a. Absorbs heat as it evaporates b. 3. Used to insulate steel and wood structural members a. The water content will be driven out in a fire and gypsum can fail b. The exposed structural members can then fail due to the higher temperatures

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	G. Glass and fiberglass 1. Glass is not used for structural support a. Sheets of glass are used for doors and windows b. Will crack and shatter from heat and water application c. Not an effective barrier to fire extension 2. Fiberglass typically used as insulation a. The glass component is not a fuel source b. The resin and binding materials can be combustible and difficult to extinguish **IV. Classifications of Building Construction Types** *(Essentials p. 146)* A. Construction classifications are based on the material types used and the fire-resistance rating of the major structural components B. Fire-resistance ratings are based on how long a material will maintain its load-bearing integrity in a fire C. NFPA 220, *Standard on Types of Building Construction*, divides construction categories into five types based on the combustibility of the structural members used and assigns a number to each type D. Type I 1.

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	2. Structural members, including walls, columns, beams, floors, and roofs are of approved noncombustible or limited combustible materials 3. Fire-resistive concrete and structural steel are protected by flame-retardant insulation sprayed on to increase the rating 4. Structural members have fire resistive ratings of not less than: a. Exterior and interior bearing walls and columns: 3 to 4 hours b. Beams, girders, trusses and arches: 2 to 4 hours c. Floors: 2 to 3 hours d. Roofs: 1½ to 2 hours 5. The primary fire hazards are the contents and interior finishes due to the construction materials resistance rating 6. Fire behavior expected in Type I construction a. Resists direct flame impingement - b. Confines fire well -fire spread through concealed spaces is reduced and more readily controlled c. Little collapse potential from the effects of fire alone - usually designed to withstand major fire exposure without major structural damage

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	d. Major causes of flame and smoke spread are breaches in the walls and ceilings e. Difficult to breach for ventilation, access or escape f. Structural components retain heat E. Type II 1. 2. Structural members, including walls, columns, beams, floors, and roofs are of approved noncombustible or limited combustible materials 3. Structural members have fire resistive ratings of not less than: a. Exterior and interior bearing walls, columns, beams, girders, trusses, arches, and floors: 1 to 2 hours b. Roofs: 1 hour 4. 5. Buildings often have flat, built-up roofs a. Consist of combustible or noncombustible decking covered with combustible felt, noncombustible insulation and tar b. Fire extension can cause the entire building to be involved

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	6. Fire behavior expected in Type II construction a. Structural elements are generally the same as with fire resistive b. Confines fire well - fire spread through concealed spaces is reduced and more readily controlled c. Fire ignition involving the building itself is less likely d. Easier to ventilate than Type I e. Difficult to breach for access or escape f. g. Steel components may be weakened by rust and corrosion F. Type III 1. 2. Exterior walls and structural members are made of approved noncombustible or limited combustible materials 3. Interior structural members, including walls, columns, beams, floors, and roofs are wholly or partly of wood of smaller dimensions than required for heavy timber construction 3. Fire resistive rating of structural members of not less than: a. Exterior bearing walls: 2 hours

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	b. Interior bearing walls, columns, beams, floors, and roofs: 0 to 1 hour 4. Fire behavior expected in Type III construction a. Unless the combustible structural components are protected, the structure is equally as subject to fire damage as wood frame b. c. Fire may spread undetected due to many concealed spaces - fire stopping is essential to limit fire spread d. Penetration of walls by doors is very common e. Heat may cause the rapid expansion of steel joists causing exterior walls to be pushed outward or roof collapse G. Type IV 1. 2. Used in old factories, mills, and warehouses 3. Exterior walls and their structural members are of approved noncombustible or limited combustible materials 4. Other interior structural members, including columns, beams, arches, floors, and roofs are made of solid or laminated wood without concealed spaces 5. Must meet the requirements specified for heavy timber:

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	a. Wood supporting columns (1) Floor loads: 8-inches in any dimension (2) Roof loads: 6-inches in any dimension b. Wood beams and supporting girders (1) Floor loads: 6 x 10-inches (2) Roof loads only: 4 x 6-inches 6. Fire behavior expected in Type IV construction a. Resists failure in a fire much longer than other types of combustible construction b. c. The large dimensions of combustible members increases the fire resistance of the structure d. Can be easily ventilated vertically or horizontally e. Susceptible to fire spread from the outside F. Type V 1. 2. Exterior walls, bearing walls, floors, roofs and their supports are made wholly or partly of wood or other approved materials of dimensions smaller than heavy timber

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	3. Fire behavior expected in Type V construction a. b. All structural members are combustible c. d. Construction techniques create voids and concealed spaces which allow undetected fire spread e. Structural members themselves are susceptible to flashover **V. Hazards Relating to Building Construction** *(Essentials p. 151)* A. Fire personnel must always be alert to construction types and building features which can affect their safety B. Sizing up existing construction 1. Tightly constructed and well insulated buildings may produce ideal conditions for a backdraft 2. The older a building, the more likely environmental deterioration a. Erosion of mortar in masonry walls b. Rust and corrosion of exposed metal c. Rotting of wood 3. The combustibility of structural members - may add to flashover potential

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	4. Changes that have made by renovations or modification which changed the layout and paths of fire spread a. Structure may have been fire resistant when built but alterations over the years may have changed the resistance b. Removal of portions of load-bearing walls c. Cutting away part of structural members, such as beams or columns for piping d. Holes for pipes and air vents cut in fire walls C. Dangerous building conditions 1. Fire loading a. b. Heavy fire loading is the presence of large amounts of combustible contents c. Arrangement of the contents affects fire development and severity d. Combustible interior finishes and combustible structural members add to fire loading 2. Roof coverings a. The combustibility of roof surfaces can significantly contribute to fire spread to exposure

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	b. It may be necessary for fire fighters to use aggressive exposure protection depending on the roofing materials 3. Large, open spaces in buildings can contribute to rapid fire spread without proper vertical ventilation 4. Collapse potential a. Fire is an attack on the integrity of the structure (1) The entire system of loads and supports may deviate from the original design because of the heat produced (2) Combustible (wood) members may be burned through destroying their load bearing capabilities (3) Steel beams may expand and push out walls and columns (4) Mortar may crack and crumble between bricks and blocks weakening walls and supports (5) Reinforced concrete may crack and break up - particularly when water is applied to hot surfaces b. (1) Fire fighters and equipment may deliver an impact load in rapid time to an already weakened structure (2) Water delivered by fire streams will create impact loads

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	(3) Water absorbed by the structural components and contents adds additional weight (4) Fire fighters may have to breach bearing walls to gain entry, thus weakening the support provided by the walls (5) Ventilation procedures may cut through supporting rafters, thus weakening the roof c. Indicators of collapse potential (1) (2) Cracks between bricks or blocks (3) (4) Steel supports bowing or sagging (5) (6) Reinforcement stars on a building are an indication that the building needed additional reinforcement before the fire d. If collapse potential exists, a collapse zone should be established around the building (1) (2) Personnel may have to pass through the collapse zone to enter or leave the building but must spend as little time as possible in the zone

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	e. If collapse is imminent, all personnel must be evacuated from the building as quickly as possible (1) The collapse zone must be cleared immediately (2) D. Lightweight truss construction 1. Trusses consist of: a. Top chord b. Bottom chord c. Web members 2. Most common types: a. Lightweight metal trusses: made from a long steel bar that is bent at a 90-degree angle with flat or angular pieces welded to the top and bottom b. Lightweight wood trusses: constructed of 2" x 3", 2" x 4", or 2" x 6" boards (1) Held together by light gauge metal plates with stamped V-shaped points which penetrate wood ¼ to ½-inch ("gusset plates" or "gang nails") (2) Some lightweight wood trusses are "finger-jointed" using only spots of glue

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	c. Most commonly found in: (1) Houses (2) Apartments (3) Small commercial buildings 3. Bowstring trusses a. Found in virtually every community b. Used in buildings with large open spaces such as: (1) Car dealerships (2) Bowling alleys (3) Supermarkets c. 4. a. Typically constructed by boards glued to particle board or plywood b. Fire fighters should take similar precautions as with lightweight trusses 5. NFPA statistics show that from 1977 through 1995, thirty fire fighters were killed in 16 incidents where wood truss roofs failed while the fire fighters worked on or below them

NOTES	STUDENT GUIDE
	a. Having less mass than solid joists or beams, they burn and fail more quickly (1) Lightweight metal and wood trusses can fail after 5 to 10 minutes of exposure to fire (2) Can fail from exposure to heat only b. c. Trusses do not have any useful degree of fire resistance d. Provides for fast fire spread due to large number of vertical web members e. f. Trusses may be damaged in shipment or when erected g. When gusset plates are exposed to fire, the following factors contribute to failure: (1) The amount of load or stress is imposed on a joint (2) The ability of the plate to conduct heat causes the wood to expand and the plate to loosen (3) The outer surface of the wood chars and the plate loosens or pulls out of the wood (4) In a fire, the points of connection fail first

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	6. Fire fighting in truss construction a. Command should conduct an initial size-up using the best available information to determine: (1) The type of construction (2) To what extent it may have been damaged by fire before initiating firefighting efforts b. If fire has burned for over five minutes in truss construction: (1) (2) E. Building hazards with construction, renovation, and demolition 1. Additional fire loads may be present and ignition sources such as cutting and welding 2. Rapid fire spread can occur in buildings under construction, renovation, or demolition due to: a. Lack of wall and ceiling covering b. Lack of doors or windows c. Fire sprinklers and alarms may not be in place 3. The potential for sudden collapse is greater in these types of buildings

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	4. These buildings can have additional risks for fire personnel a. Accumulations of debris and construction materials can block exits b. Contractors do not always follow fire codes c. A second roof may be constructed over an existing roof d. Concealed spaces may be added where fire can spread undetected 5. With the additional risks involved, fire officers must do a quick risk/benefit analysis before ordering fire fighters inside a building under construction or demolition 6. If everyone has escaped the building and there are no risks other than the structure, the decision may be made to fight the fire defensively a. A building under construction with significant fire damage will usually be demolished before rebuilding b. It should be asked if there is any real loss if the fire is in a building being demolished c. **VI. Building Construction Summary** A. Understanding how buildings are constructed can help give fire fighters an added measure of safety

NOTES	STUDENT GUIDE
	1. Fire behavior and spread is affected by construction types and methods 2. The type of a structure's construction can contribute to a fire B. Fire fighters must always remember the additional hazards involved with certain construction methods and materials 1. 2. Collapse potential must continually be evaluated at any structural fire, regardless of the construction type C. A risk/benefit analysis needs to be conducted by officers before any fire building is entered by personnel to determine if the potential benefits outweigh risking fire fighters' lives