FireWise CONSULTING LEARNING ACADEMY

Fire Inspector I

CHAPTER TWO

BUILDING CONSTRUCTION

Part 2

Slide 1	Welcome to Chapter 2 - Part 2 Building Construction. In this Part we will discuss: • Types of construction in both Canada and the US • Building loads being live loads or dead loads • Floors and ceilings as fire separations • Roof structures and design • Types of walls • Structural support
Slide 2	The definitions of the types of construction vary from Canada to the US. In Canada the building code refers to three types of construction as follows: • Combustible construction means that type of construction that does not meet the requirements for non-combustible • Non-combustible construction means that type of construction in which a degree of fire safety is attained by the use of non-combustible materials for structural members & other building assemblies. • Heavy timber construction means that type of combustible construction in which a degree of fire safety is attained by placing limitations on the sizes of wood structural members & on the thickness & composition of wood floors & roofs & by the avoidance of concealed spaces under floors & roofs.
Slide 3	In the US, NFPA 220: Standard on Types of Building Construction, categorizes buildings by their type of construction & this is often used in Canada as well. They are: **Type I -** Fire Resistive, which is the least combustible, **Type II -** Non-combustible, **Type III -** Ordinary combustible, **Type IV -** Heavy timber; & **Type V -** Wood frame, which is the most combustible.
Slide 4	Type 1 Fire Resistive buildings are built with non-combustible structural members & must meet relevant NFPA or local building code fire resistance specifications. Structural components include walls (interior & exterior), partitions, columns, floors & roofs.

	Type 1 Construction is commonly found in large buildings such as schools, hospitals & high-rise buildings which are usually constructed using reinforced concrete & protected steel frame construction. Structural steel frame material must be protected from the heat of a fire because of its tendency to loose strength at high temperatures. The use of some combustible materials is permitted for non-structural elements such as roof coverings, some insulation materials, & limited amounts of wood interior finish & flooring. Due to the tactical challenges involved in fighting fires in high-rise buildings, they are designed & built to be the most fire resistive.
Slide 5	Type II – Non-combustible buildings are built using non-combustible or limited combustible structural elements, but the requirements are less stringent than for Type 1 construction. Non-combustible construction is very common in low-rise commercial & industrial building as permitted by the local building code. Most have some degree of fire resistance; normally 1 or 2 hours for exterior walls & roof. An example of this type of construction is the common tilt-up concrete building.
Slide 6	Type III – Ordinary Construction – These buildings may have all or part of their interior structural elements built of combustible materials. However, exterior walls must be of non-combustible materials & all concealed spaces must be appropriately fire-stopped. A general definition of ordinary construction would be a building featuring exterior masonry walls & combustible interior beams or truss. Ordinary construction is often found in strip malls with pre-cast blocks & lightweight engineered wood trusses. Ordinary construction buildings have a history of difficult fires because of void spaces between floors & in the attic where fire can go undetected & be difficult to reach. As well as the combustible nature of the construction, they often have a significant fuel load based on their use.
Slide 7	Type IV – Heavy Timber buildings are constructed where the structural members; columns, beams, arches, floors & roofs, are built entirely of unprotected wood, minimum of 6” – 8” dimension, with large cross-sectional areas.

	No concealed spaces are permitted. Non-combustible or limited combustible materials with a minimum fire rating of 2 hours, can be used in both interior & exterior load-bearing walls. Years ago, most buildings of this type were built as large mills or warehouses. Today most heavy timber construction is used as a design feature for aesthetics & in many cases it is not really heavy timber. One of the desired features is the mortise & tenon joints that connect two pieces of wood. Woodworkers around the world have used mortise & tenon joints for thousands of years because it is simple, strong & pleasing to the eye.
Slide 8	"Mill" construction was an early form of Timber Frame construction developed by the insurance industry. They often had masonry walls & heavy timber frame. Generally, they were sprinklered with scuppers in the side walls of the structure, for purposes of draining water. The scuppers are usually placed at or near floor or ground level & allow water to flow off the side of the open-air structure, instead of pooling within the walls. Mill construction also denotes floor supports designed to fail during an extreme fire event leaving the supporting walls or posts intact.
Slide 9	Type V – Wood Frame construction buildings have structural members made from wood or other combustible materials. Wood frame construction is often associated with residential construction & contemporary light-weight commercial construction. Buildings with wood structural members & a masonry veneer or other type of material covering the exterior are considered wood frame. Wood frame construction has little fire resistance because flames & hot gases can penetrate into the spaces between joists or the studs, allowing fire spread outside of the area of origin.
Slide 10	In balloon frame construction, the studs go from the foundation wall to the roofline. This type of construction is typical in many homes built prior to 1940. They were built without fire stopping, allowing a fire that has developed in the wall to rapidly extend into the attic.
Slide 11	In balloon frame construction the floor joists are attached to the walls by the use of a ribbon board. Where fire stopping is present, buildings of balloon frame respond similarly to buildings of platform construction. Almost all building codes require fire stopping of all vertical channels in balloon frame buildings. Fire stopping could include non-combustible materials such as brick or dirt, & more recently with insulation. In some situations, builders would remove fire stopping to allow for convenient installation of utilities such as wiring, plumbing or HVAC.

Slide 12	At one time the balloon frame system of construction was widely used for smaller buildings. Because fire stopping was not required, there were many vertical channels from the basement to the roof, so fire extension easily occurred upward or downward. Horizontal joists open ended to the vertical channels allowing fire to enter the vertical channels & rapidly spread from floor to floor & into the attic.
Slide 13	Platform construction is the most common construction method currently used for residential & light-weight commercial construction. Fire spread is a concern in this type of construction because combustible materials are used & there are concealed spaces in the structural elements which allows a fire to develop & spread without detection.
Slide 14	Platform construction is found in the majority of small buildings. They are very combustible, have concealed spaces, & limited fire separation. This type of construction inherently provides fire barriers to vertical fire travel as a result of the configuration of the stud channels. However, these barriers in wood frame construction are combustible & may be breached during a fire allowing the fire to spread to other spaces. Vertical fire spread may also occur in platform construction through utility paths, such as electrical, plumbing, & HVAC. Openings for utilities in wall stud spaces may allow easy passage of fire from floor to floor.
Slide 15	Plank & beam construction uses larger beams that are widely spaced & supported by posts. The decking for floor & roofs is planking in minimum thickness, in place of plywood sheeting. Most planking is tongue & groove, which will slow the progression of fire. Instead of bearing partitions supporting the floor or roof joist or rafter system, the beams are supported by posts. Generally, there is only a limited number of concealed spaces to allow a fire to spread. Failure of the spaces between timbers may occur leaving large frame members still standing. Interior finishes in these structures often have large areas of exposed, combustible surface that may allow flame spread over its surface resulting in rapid fire development & spread.
Slide 16	Post & Beam construction is similar to Plank & Beam construction in that the structure utilizes larger elements, & the frame is provided to attach the exterior finish. An example of this type of construction is a barn, with the major support coming from the posts & beams, & the frame providing a network for the exterior finish to be applied.
Slide 17	Geotechnical engineering is the application of soil & rock mechanics in the design of foundation elements of structures. In engineering terms, a

	foundation is what connects the building to the ground, & transfers loads from the structure to the ground. The foundation is built on a footing which can be seen in this picture. The purpose of footings is to support the foundation & prevent settling. A footing is placed below the frost line & then the foundation walls are added on top. As buildings naturally move due to settling, moving of the soil, or earthquakes, the foundation must be able to carry both dead loads & live weight loads.
Slide 18	Dead loads are constant & immobile. They may include the building structural components such as floor slabs, structural columns, roof coverings, HVAC mechanical units, elevator machinery & other building systems. Live loads are the weight of the building contents which can vary. Typically, live loads include the anticipated weight of people, furniture, appliances, automobiles, moveable equipment etc. There are also environmental loads that designers should account for. Environmental loads can come from snow, wind, soil movement & seismic activity.
Slide 19	In multistory buildings floors & ceilings often become important fire resistive barriers to the development & spread of fire & smoke. Concrete floors are common & can be poured in place or pre-cast. They may be self supporting or supported by steel beams or trusses. In the latter case the ceiling below the supported concrete floor can provide a thermal barrier to protect the steel from a fire. Wood floor systems are common in building construction. They range from heavy timber to modern lightweight construction. Heavy timber will withstand fire for a long time, but conventional wood flooring is much lighter & can be expected to fail more quickly than heavy timber. Modern lightweight truss systems utilize wooden trusses, or “I” beams covered with decking material. These systems can burn through rapidly & the structural elements can fail quickly in the event of a fire.
Slide 20	Ceilings are often thought of as a decorative finish, but they can also play a role in the required fire separation of the room or floor area. Fire inspectors must be aware of the intended function of the ceiling system as damage may affect the overall performance of the fire separation. A rated ceiling acts as a thermal barrier to the heat from a fire below. A suspended ceiling may also be a part of a fire rated floor & ceiling assembly. Both the T-bar & the tiles must be rated & approved for use.

	Removing a single ceiling tile from such assemblies will void the fire separation rating. Similar assemblies are used in buildings not required to be fire resistive. In such cases, the ceiling tiles need meet only flame spread requirements. This provides no rated fire resistance.
Slide 21	As a fire inspector, you must be able to recognize various types of roof structures & materials. The most common roof types are the Pitched, Curved or Flat roof. **Pitched roofs** are used extensively in homes & some commercial buildings. There are various types of pitched roofs including: **Gable roofs** only slopes in two directions & is open on the ends. The sloped sides meet along a central ridge. The triangular section of the wall between the pitched sides at each end are called gables. The gables are what give this style of roof its name. **Shed roofs** are one directional flat sloping roofs. **Butterfly roofs** are basically 2 shed roofs joined together. **Gambrel roofs** are usually symmetrical two-sided roofs with two slopes on each side & are often called Barn roofs.
Slide 22	• A **monitor roof** is a raised structure running along the ridge of a double-pitched roof, with its own roof running parallel with the main roof. • A **saw-tooth roof** is a roof comprising a series of ridges with dual pitches either side. The steeper surfaces are glazed & face away from the sun to shield workers & machinery from direct sunlight but allows natural light into the building. • A **mansard roof** is another form of Gambrel that has four sloping sides, each of which becomes steeper halfway down. A **hip roof** has all sides sloping downwards to the walls & has no gables or other vertical sides to the roof.
Slide 23	Traditional curved or arched roofs were made of stone but are used in modern architecture to provide a unique style. They can be self-supporting. An Arched, or curved roof is often used for supermarkets, warehouses, arenas & other large buildings that require large, open interior. Flat roofs are found on houses, apartment buildings, shopping centers, schools & hospitals. Most flat roofs have a slight slope so that water can drain off the structure. If the roof does not have the proper slope or if the

	drains are not maintained, water may pool on the roof, overloading the structure & causing a collapse.
Slide 24	Roof decking can be constructed of tile, slate, wood, steel or concrete. The material used depends on the building's age & size, the climate, & the cost of material. Underlying materials may be felt, foam insulation, tar paper or a synthetic vapour barrier. This creates a built-up roof covering that may contain up to five layers. Some of these materials will be fire resistive, therefore difficult to light, but once on fire they can add to the fuel load of the structure. During build or renovation inspections, you should ensure that there are no void spaces under the roof which can add to fire travel. When conducting a fire inspection, be aware of the possible presence of asbestos in any void space under a roof & wear appropriate PPE when required. Older buildings may have multiple roofs. Due to a variety of problems, a new roof may have been installed over an existing roof, or a pitch roof was built over a flat roof. These circumstances can be difficult in the event of a fire so you should identify this in the pre-incident plan. Any void spaces should be identified.
Slide 25	Many roofs & floors are supported using trusses. A truss is a structure with straight pieces forming triangles to support a load. When the members of the triangles are placed under tension & compression, they do not bend. There are three common types of trusses used in modern construction. They are the parallel cord truss, pitched cord truss, & bowstring truss. The parallel cord truss, as seen in this photo, gets its name from having parallel top & bottom chords which are connected by a series of triangles. This type of truss is often used for floor construction but can also be used in roof applications. The top & bottom members are called cords while the connecting pieces are the web members. The chord size & web configuration are determined by span, load & spacing.
Slide 26	The pitched cord truss is typically used to support sloping roofs found in most modern residential construction. The roof deck is attached to the top cord & the ceiling of the living space is attached to the bottom cords. Bowstring trusses are so named because the shape of their curved top chords & horizontal bottom chords resemble an archer's bow & string. They are used when there is a need for a large, open floor area, without the inhibiting presence of columns or posts. One of the most dangerous

	aspects of a wooden bowstring truss system is the large area in which smoke & heat from a fire can develop.
Slide 27	Walls are the most readily visible parts of the building & may be constructed from many different materials. Terminology for walls that you should be familiar with are Load bearing & non-load bearing. Load-bearing walls support the weight of a floor or roof structure above & are so named because they bear a load. By contrast, a non-load-bearing wall, sometimes called a partition wall, is responsible only for holding up itself. Any part of a load-bearing wall that is removed must be replaced with a suitable structural support, such as a beam and/or columns to bear the same load that was supported by the wall. Generally, when the wall in question runs parallel to the floor joists above, it is not a load-bearing wall. But if the wall runs perpendicular (at a 90-degree angle) to the joists, there is a good chance that it is load bearing. However, there are cases where a bearing wall is parallel to the joists so if in doubt consult a professional.
Slide 28	In addition to load bearing & non-load bearing there are other walls that may be used in construction. A party wall, also known as common wall, is a dividing partition between two adjoining buildings that is shared by the occupants of each residence or business. Typically, the builder lays the wall along a property line dividing two houses, so that one half of the wall's thickness lies on each side. This type of wall is usually structural. Party walls can also be formed by two abutting walls built at different times. The term can be also used to describe a division between separate units within a multi-unit apartment complex. Very often the wall is designed to meet established criteria for sound &/or fire protection. In this case the party wall also acts as a firewall.
Slide 29	A firewall is defined by the building code as a type of fire separation of non- combustible construction that subdivides a building or separates adjoining buildings to resist the spread of fire and has a fire-resistance rating. A firewall must have the structural stability to remain intact under fire conditions for a required fire-rated time. A firewall is designed to limit the spread of fire from one side of the wall to the other. It is a portion of a building's passive fire protection system that extends from the foundation through the roof. This allows a building to be subdivided into smaller sections and in some cases does away with the requirement for a sprinkler system. To be a firewall, the wall must

	extend above the roofline. The portion of the wall above the roof is called a parapet.
Slide 30	Fire partition walls are interior walls that extend from a floor to the underside of the floor above. They can be fire rated to form part of a required fire separation. They are often used to separate rooms & corridors from the remainder of the floor area. Fire enclosures which are vertical shafts, prevent fire from spreading from floor to floor by way of vertical openings. Fire enclosures are often used as exit stair towers to protect building occupants from fire, smoke & hot gases. The stair tower must be fire separated from the rest of the building to provide a safe passage of travel to the exit.
Slide 31	Curtain walls are non-loadbearing walls attached to the outside of the building & serve as the exterior skin or cladding often on high-rise buildings. Inspectors need to recognize the materials used in the veneer as they can be highly flammable & building codes usually require any insulation to be covered with a flame protective barrier. A tragic example of a curtain wall fire occurred in the 24-storey Grenfell Tower apartment in London England causing 72 deaths. More than 70 others were injured, & 223 people escaped. It was the deadliest residential structure fire in the United Kingdom since the Second World War. The fire was started by a malfunctioning fridge-freezer on the fourth floor which spread rapidly up the building's exterior. This was due to the building's exterior cladding. It burned for about 60 hours before finally being extinguished. Fire safety experts have said that the building's external cladding was a possible cause of the rapid spread of the fire. Experts said the gap between the cladding & the insulation worked like a chimney to spread the fire. **Partition wall**: a non-bearing interior wall that can be easily removed & replaced. These walls are common in office buildings where the needs of the tenants can change.
Slide 32	Partition walls are non-bearing interior walls used to separate internal spaces into rooms or functional areas that can be easily removed & replaced. These walls are common in office buildings where the needs of the tenants can change. The do not provide fire separation.

Slide 33	Columns have been used as structural support members for hundreds of years. Columns or pillars in architecture & structural engineering terms are a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other words, a column is a compression member frequently used to support beams or arches on which the upper parts of walls or ceilings rest. For the purpose of wind or earthquake engineering, columns may be designed to resist lateral forces. Modern columns are often used for decorative purposes & not needed for structural support. The term column typically applies to a large round support. A small wooden or metal support with a rectangular shape is typically called a post.
Slide 34	Beams, girders, joists & rafters are structural members that sit on walls, columns or posts to provide horizontal or diagonal support for other loads. Beams are usually support at each end or at intermediate points depending on the load it carries. Beams can be used to support a load on top of it or can have a load suspended under it. In the case of the beam in this picture, it is supporting a load above & is used as an anchor point for floor trusses. Beams can be metal, solid wood, laminated wood, or manufactured of lightweight materials.
Slide 35	Manufactured wood beams are often referred to as glulam beams as glue is a major component. Laminated beams are usually large dimension & behave like heavy timbers until the heat of the fire begins to adversely affect the structural stability. Laminated beams are like heavy timber because their mass will support loads longer than dimensional lumber & unprotected steel beams. Laminated beams are designed for interior use only. The effects of weather may decrease the load-bearing capabilities of the beam & this should be considered if the beam has been exposed to water or other similar conditions.
Slide 36	A girder is a large beam that supports other smaller beams or joists. A girder may be made of timber, steel, reinforced concrete, or a combination of these materials. Steel & concrete girders are usually found in heavy construction like bridges and high-rises while light weight metal & wood girders are used in lighter construction projects.

	Wooden girders are more common than steel in light-frame buildings. Common types of wood girders include solid, built-up, hollow, & glue laminated. Girders carry a large part of the building weight. They must be rigid & properly supported at the foundation walls and on the columns or posts. A girder should be large enough to support the intended load. For greater carrying capacity, it is better to increase a girder's depth than width. When the depth of a girder is doubled the safe load increases four times. For example, a girder 3 inches wide & 12 inches deep will carry four times as much weight as a girder 3 inches wide & 6 inches deep. Lightweight wood & metal girders are often used in low-rise light industrial buildings. They are cost effective but can fail rapidly when involved in a fire.
Slide 37	A joist is a support member for a floor or roof assembly. A rafter is similar but specifically used to support a roof system. In this photograph of platform residential construction, a second-floor level will be added on top of the floor joists. A joist is a horizontal structural member used in framing to span an open space, often between beams that subsequently transfer loads to vertical members. When incorporated into a floor framing system, joists serve to provide stiffness to the subfloor sheathing, allowing it to function as a horizontal platform. Joists are often doubled or tripled, placed side by side, where conditions warrant, such as where wall partitions require support. Joists can be made of wood, engineered wood, or steel. Typically, wood joists are made with dimensional lumber with the longer surface positioned vertically. Modern residential construction often uses engineered wood joists in place of dimensional lumber.
Slide 38	Wood I-Beams are constructed with small dimension or engineered lumber, as the top & bottom chord, with Oriented Strand Board or (OSB), or plywood as the web of the beam. These members are generally thinner than the structural members they replace. As a result, burn-through of the web & resulting failure can occur more quickly than is generally predicted with the use of dimensional lumber. This failure can cause early collapse of floor or ceiling assemblies. Breaches in the web for utilities may allow for fire spread through these spaces & result in earlier failure. Unlike wood trusses, wood I- Beams will confine fire to the joist space for a period of time.

Slide 39	Engineered trusses are the framework of light-weight dimensional lumber designed to bridge the space above a room & to provide support for a roof. Because they are manufactured using lightweight dimensional wood, which is pre-assembled, they are cost effective & very common in residential construction. A typical roof truss, as shown here, fastens the chords, the truss web, & the king post together using metal gusset plates to give the truss its strength. Gusset plates are stamped sheet fasteners which contain spikes that hold the truss components together. The spikes have very little depth, normally ranging from 3/8 inch or 10 millimeters to 1⁄2 inch or 12.7 millimeters. Therefore, the spikes do not protrude into the wood very deep but there are many spikes in a small area holding the structural members together.
Slide 40	Metal gusset plates readily conduct heat. Because they are metal, they can expand rapidly when subjected to heat & transfer the heat into the wood creating charring. The gusset plates can separate from charred wood members resulting in the roof structure collapsing.
Slide 41	That's the end of part two of Building Construction. In this part we discussed: • Three types of construction in Canada – Combustible, Non-combustible, and Heavy Timber which differs from the five types of construction identified in the US as types 1 through 5. • That Type 1 construction is the most fire resistive while Type 5 is the least fire resistive. • Type 2 is non-combustible, but the requirements are less stringent than Type 1 • Type 3 is ordinary construction, where all or some parts of the interior structural elements are combustible, but the exterior walls must be non-combustible. • Type 4 is heavy timber and type 5 is wood frame. • In balloon framing, the studs go from the foundation to the roofline and may lack fire stopping.
Slide 42	We talked about • Building loads being either dead loads or live loads. Dead loads are constant while live loads may change. • Floors & ceilings often become important fire resistive barriers

	• There are different roof types, but the most common are pitched, curved, and flat. • Void spaces under roofs can contribute to fire spread. • Older building may have multiple roof layers which should be identified in pre-fire planning. • Most wood roof trusses gain strength by triangle design. • Bowstring trusses are used to cover large spans. Load bearing walls usually run perpendicular to joists.
Slide 43	• Fire walls extend from the foundation through the roof. If it does not parapet the roof it is not a fire wall but may be a fire separation. • Fire partition walls are interior walls that extend from a floor to the underside of the floor above. • Curtain walls are nonloadbearing walls attached to the outside of the building and are normally used for decorative purposes. • Laminated beams are designed for interior use only. • Lightweight wood & metal girders are often used in low-rise light industrial buildings. • Wood I-Beams are constructed with small dimension or engineered lumber, with OSB, or plywood as the web of the beam. Burn-through of the web can cause early collapse of floor or ceiling assemblies. • We finished Part 2 talking about how metal gusset plates conduct heat and expand rapidly resulting in potential roof collapse. Please move on to Part Three.