WHY WE BUILD THE WAY WE DO

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EXPERIENCE, BUILDING SCIENCE (HOUSE AS A SYSTEM) AND BUILDING CODES

Course Outline

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EXPERIENCE, BUILDING SCIENCE (HOUSE AS A SYSTEM) AND BUILDING CODES

Learning Objective:

To understand that Canadian construction practices are based on experience of over 100 years' experience, building science principles and the building codes

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THE HOUSE AS A SYSTEM

Learning Objective:

To understand that the performance of a house is directly related to the construction of the building envelope, how the mechanical systems operate, the local climate and the occupant's lifestyle

The control of heat flow, moisture flow and air flow in a home is influenced by

- The construction of the building envelope – how airtight it is and how well insulated it is
- The operation of the ventilation system – is the house well ventilated or not, does the ventilation or heating system put the house under a negative or positive pressure
- The outdoor climate – temperature, sunlight, wind and rain
- How the occupants operate the home, do they produce a lot of moisture, do they operate the ventilation system all the time etc.

THE BUILDING ENVELOPE

Learning Objective:

To understand the functions of the building envelope in terms of energy use, comfort durability and human health

To provide comfortable durable housing the building envelope must incorporate the following

- A barrier to heat transfer – insulation
- A barrier to air movement – air barrier
- A barrier to rain penetration –cladding, rain screen and building paper
- A barrier to the movement of internally generated moisture - vapour barrier and air barrier

THERMAL BARRIER

Learning Objective:

To understand for insulation to perform it must be kept dry and air must not be allowed to circulate through it or around it

Insulations all function by encapsulating a gas usually air in small cells. As long as the air is kept still it is a good insulator. The performance of batt or blown insulation will be reduced if wind can blow through them so these types of insulations must be protected by the use of sheathing papers over walls and insulation baffles at the edge of ceiling cavities. If insulation does not completely fill a stud cavity air will circulate by natural convection. In the winter the air next to the exterior sheathing will cool down dropping to the bottom of the cavity and then will be heated as it comes into contact with the interior finish causing it to rise. This circulation of air transfers heat bypassing the insulation and may cause interior finishes to cool enough to cause condensation. In the summer the reverse will happen causing more heat to be gained through the wall increasing air conditioning loads.

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INSULATION CONTINUITY

Learning Objective:

To understand why and how truss roofs can be insulated to reduce heat losses and minimize the possibility for condensation

Where a roof truss meets an exterior wall the roof insulation thickness is typically reduced, this increases heat losses and will cause the interior finishes next to this area to be cooler in winter possibly leading to condensation. These problems can be remedied by using a raised heel roof truss that allows full depth ceiling insulation to be taken to the outside of the exterior wall. The insulation must be retained at the edges of the truss with an insulation baffle which allows ventilation between the roof sheathing and the top of the insulation and also prevents wind washing that would lower the thermal resistance (increase the conductance) of the insulation.

OPTIONS FOR INSULATING BASEMENTS

Learning Objective:

To understand the options for insulating basements

Basements can be insulated on the interior or the exterior

Exterior insulated basements typically consist of a concrete block or a poured concrete wall with a damp proofing applied over the outside face of the concrete and a rigid insulated applied over the damp proofing. The rigid insulation is typically protected above grade with a sheet metal flashing and cement board, preservative treated plywood or stucco. The types of rigid insulations used include extruded polystyrene, high density expanded polystyrene, rigid mineral wool board or high density fiberglass board. Fiberglass board and mineral wool boards as well as specially fabricated foam board insulations may also act as a drainage plane diverting ground water that runs up against the foundation and directing it down to the drain tile.

- Exterior Insulation Pros
- Exterior Insulation Cons

Interior insulated foundations typically consist of a wood frame wall located behind a concrete block or poured concrete wall. The wood frame wall is typically insulate with glass fiber insulation and a vapour barrier is installed as per conventional above grade wood frame construction. The wood frame wall must be separated from the concrete wall by an air space of 12mm (1/2”) or more or by a capillary break to prevent moisture movement into the framing. Variations on this approach include placing extruded polystyrene foam insulation against the inside face of the concrete wall with adhesive then placing an uninsulated wood frame wall against the extruded polystyrene, no vapour barrier is installed over the framing. This last approach protects the framing from moisture entry from the concrete and allows for drying of the wood frame cavity to the interior.

- Interior Insulation Pros
- Interior Insulation Cons

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INSULATED CRAWLSPACES

Learning Objective:

To understand the insulation options for conditioned crawlspace foundations

Crawlspaces can be insulated around the perimeter walls and also on or beneath the crawlspace floor slab. If this is done along with controlling moisture entry by placing a moisture barrier under the floor slab the crawlspace can be heated which has a number of benefits including

- Services run in the crawlspace are protected from freezing
- The floor over the crawlspace is kept at room temperature enhancing thermal comfort
- The crawlspace can be used for dry heated storage area
- Ground moisture from the crawlspace floor is eliminated
- The wooden floor structure is protected from outdoor conditions and is hence more durable

There are two options for insulating condition crawlspaces those are placing the insulation on the exterior of the foundation wall or placing it on the interior of the foundation wall. Both methods are illustrated in the slide above. In both cases a rigid insulation typically foam plastic is placed against the concrete foundation wall. In the case of the interior insulation option the foam board is nailed to the wall with a concrete nail and large plastic washer and / or glued to the wall with an adhesive. The foam board is stopped at the top of the concrete wall and the rim joist is insulated and air sealed with expanding urethane spray foam. In the exterior insulation case the rigid insulation is run from the footing to the top of the rim joist and covered with a durable finish such as pressure treated lumber, concrete board or stucco. A flashing is carried over the top of the foam to direct water away. The rim joist area is air sealed by air sealing the sill plate to the top of the concrete wall with a one part urethane sealant and gluing the rim joist to the sill plate and the underside of the subfloor above with a continuous bead of construction adhesive.

If local conditions dictate that there is no excavation for the crawlspace then both the short vertical wall and a one meter wide perimeter strip of the crawlspace floor slab should be insulated.

SLAB ON GROUND

Learning Objective:

To understand insulated slab on grade foundations

Slab on grade or slab on ground foundations are widely used in some areas for their ease of construction and low cost. They can be constructed with either a separate footing and foundation wall and slab or as a monolithic slab with thicken footings. In both cases the heat loss through the edge of the foundation is extremely high so it is critical the slab be insulated at it’s perimeter either at the inside or outside. In addition a one meter (300mm) wide strip of foam insulation must be placed around the entire slab perimeter to further reduce heat losses. If in-floor radiant heating is used the entire underside of slab must be insulated.

For hot humid and mixed climates the builder may wish to insulate under the entire slab to reduce the possibility of condensation forming on the top side of the slab for periods when the air conditioner / dehumifier is not in use. In many cases if the slab is at ground temperature it will be below the dew point temperature of the outdoor air. In termite areas termite entry must be considered when choosing how to insulate. A termite mesh can be located beneath the insulation to protect it or termite proof insulations such as foamed glass may be used.

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THERMAL BRIDGING

Learning Objective:

Understand the difference in thermal properties between wood and steel stud wall assemblies and the concept of thermal bridging.

The overall thermal resistance of a wall assembly is determined by the thermal resistance of the all the components of the wall assembly and their relative surface areas. When comparing two wall assemblies it is important to look at the overall or composite thermal resistance. If a material in the assembly has a high thermal conductivity compared to insulation it is referred to as a thermal bridge. In a wood frame wall the wood framing conducts more heat than the insulation so it is the cause of thermal bridging in that type of assembly. Steel studs are similar except that they conduct heat much more readily than wood so their thermal bridging has a much greater effect on the overall thermal resistance of the wall assembly. Thermal bridging can be reduced through the use of insulated sheathings that provide a thermal break between the outside conditions and the framing material. This slide compares the thermal performance of wood and steel frame walls both incorporating a rigid insulated sheathing as a thermal break. The steel stud wall performance is improved but it still has a thermal resistance only 78% that of the wood frame wall assembly.

ENERGY EFFICIENT CONSTRUCTION

Learning Objective:

To understand the many benefits of energy efficient construction

Energy efficient construction has many benefits for both the homeowner and society as a whole. It reduces operating costs in both heating and cooling climates, provides a more comfortable and healthier indoor environment and reduces the combustion of fossil fuels that leads to greenhouse gas emissions

AIR BARRIER

Learning Objective:

To understand that uncontrolled air flow has an impact on energy use and building durability

- Uncontrolled air leakage through exterior walls, floors and ceiling will contribute to heat losses in the winter and heat gains in the summer because the air leaving is replace by outside air that has to be heated or cooled.
- Wind washing of insulation disturbs the still air contained in loose fill and batt insulation reducing its thermal resistance (increasing the thermal conductivity)
- The majority of water vapour that moves through wall, floor and roof assemblies does so by hitching a ride with air leaking through those assemblies. When the air comes into contact with surfaces that are below the dew point temperature condensation occurs. This phenomenon can occur in both heating and cooling climates.
- Random uncontrolled ventilation does not ensure good indoor air quality because the quantity and distribution of the air movement is not known or controlled.

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ENVELOPE AIRTIGHTNESS

Learning Objective:

To understand the typical locations for air leakage in a wood frame low rise residential building

Uncontrolled air leakage can occur in many locations in a home. The figure on the slide here shows many of those locations. These typically tend to be where joints occur between materials, at windows and doors and at electrical, mechanical and plumbing penetrations. The rim joist area is a location in which air can enter and then can make it's way through all connected floor joist and partition wall cavities. Air leakage can also occur through mechanical equipment such as furnace, boiler and water heater flues as well as through exhaust fans. Soil gases such as water vapour, methane and radon may enter through the foundation if that area is under a negative pressure.

CONTINUITY OF AIR BARRIER

Learning Objective:

To understand the necessity for air sealing the rim joists

The rim joist is typically one of the largest areas of air leakage in a building and is a key detail that has to be resolved

CONTROLLING MOISTURE MOVEMENT

Learning Objective:

To understand that moisture is the major cause of building deterioration and creates unhealthy living conditions

Moisture accumulation on interior surfaces and inside wall floor and ceiling cavities can lead to rot and mold growth. Mold spores can cause strong allergic reactions in some people. Building envelope durability involves in part ensuring that the wood structure and interior finishes stay dry preventing rot and mold growth.

MOISTURE MOVEMENT BY DIFFUSION

Learning Objective:

To understand how water vapour moves by vapour diffusion

To understand how water vapour moves by air leakage

Water vapour moves from areas of high humidity to areas of low humidity by diffusion. Materials resist the movement of water vapour by diffusion by varying degrees. Those that let water vapour pass through readily are vapour permeable, drywall and wood such materials. Materials that resist water vapour diffusion are vapour impermeable, aluminum, polyethylene and glass are vapour impermeable materials. The slide gives an example of the amount of vapour diffusion that occurs over a heating season through a one square meter of drywall.

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VAPOUR BARRIER

Learning Objective:

To understand the importance and function of a vapour barrier

Vapour diffusion must be controlled to prevent accumulation of moisture inside insulated cavities. This is done by placing the vapour barrier in a location where is always in contact with air that is above it's dew point temperature in other words is located on the warm side of the insulation. In heating climates this would be on the inside, in hot humid climates this would be on the outside and in mixed climates a vapour barrier can be located in the middle of the wall. Vapour barrier or vapour retarder materials are defined by the Canadian building code as those materials with a vapour permeance of 15 nanograms Pascal meter squared ($ng/Pa \cdot m^2$) or 0.25 in imperial units $grain/ft^2 hr (in \cdot Hg)$ or less. Typical vapour barriers include polyethylene, aluminum foil, glass, steel etc. Some materials also have a low enough permeance to air flow that they can also be used as an air barrier in certain applications (there are other considerations for air barrier such as the ability to withstand wind loads etc.)

INTERIOR VAPOUR AND EXTERIOR WATER

Learning Objective:

To understand the causes of moisture movement in buildings

- Wood with elevated moisture content is subject to rot, so for a wood structure to be durable it is necessary that it remains dry throughout it's service life.
- Rain entry into wall assemblies can be prevented by deflection (overhangs, flashing and sills) drainage (rain screen) use of durable materials (cedar and preservative treated wood) and by allowing for drying.
- Exterior moisture (humidity) in hot humid climates is best resisted by a low permeance sheathing and no vapour barrier on the inside to promote drying in that direction.
- Interior moisture entry into insulated cavities should be prevented through placement of vapour barrier materials (location and type dependent on climate) and the use of an air barrier.
- Humidity sources in the home should be controlled through ventilation (range hoods, bath fans and HRV's) and by sealing off sources of ground moisture such as crawlspace floors, slabs on grade and basements floors and walls through the use of drainage, capillary breaks and polyethylene moisture barriers

RAIN PENETRATION CONTROL

Learning Objective:

To understand the four basic strategies for preventing rain penetration of walls
In order of effectiveness the following are the strategies for preventing rain penetration of exterior walls

- Deflection
- Drainage
- Durable materials
- Drying

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RAIN SCREEN CLADDING

Learning Objective:

To acquaint the audience with rain screen construction

Rain screen construction is the most effective way of protecting a wall from rain penetration. A rain screen involves mounting the cladding 12mm to 19mm out from the WRB and sheathing. This provided both a drainage plane and a capillary break and protects the WRB from exposure to surfactants that may leach out of the cedar and stucco claddings. All items such as windows, doors and vents that pass through the drainage plane must be protected with a cross cavity head flashing tucked beneath the WRB. This type of flashing will prevent water draining down the wall cavity from penetrating window and door frames as well as entering the wall assembly. In many cases a continuous through wall flashing is placed at the floor line to redirect water out of the wall, a gap at this location also will accommodate framing shrinkage in the rim joist and wall plates. A rain screen in combination with a structurally supported air barrier can also help neutralize the force of wind that drives rain into a wall assembly. As the wind blows against the wall, if the cavity behind the cladding is compartmentalized, pressure will build up in the cavity approaching or equaling the pressure of the wind, this will prevent the wind from forcing rain through openings in the cladding.

Typical rain screen construction consists of nailing vertical precut 12mm (1/2") thick pressure treated plywood strips nailed in place with hot dipped galvanized or stainless steel nails. Plastic or stainless steel mesh is located at the bottom of each cavity to prevent insect entry.

WOOD FRAME ASSEMBLIES ARE DETAILED FOR LOCAL CLIMATIC CONSIDERATIONS

Learning Objective:

The need to adapt wood frame construction to local conditions

INSECT RESISTANCE

Learning Objective:

To understand how to prevent insect infestation

- Wood is more attractive to insects when it has a higher moisture content so protecting wood from condensation and precipitation as well as ground moisture will reduce the possibility of insect damage.
- Maintaining a dry foundation by use of a capillary break in the form of 150 micrometer (6 mil) polyethylene and sub-slab and perimeter drainage will reduce the likelihood of insect infestation.
- Preservative treatments for lumber such as Borate and ACQ can prevent insect damage.
- Borate is nontoxic to humans and therefore can be used inside the building envelope. Borate can leach out of wood so it should not be used in applications where it is exposed to standing or running water. Entire homes have been constructed or borate treated lumber particularly where flying termites are a problem.
- ACQ is uses copper and quats as preservatives and is typically used in exterior construction situations. Stainless steel nails should be used with ACQ, obtain specific application limitations and fastener information from the manufacturer.
- Termites can also be blocked from entering a concrete foundation if a monolithic raft foundation is used that is adequately reinforced to prevent cracking
- Termites can also be blocked through the use of very fine stainless steel mesh that is made for this purpose.

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FIRE RESISTANCE

Learning Objective:

To understand that Canadian wood frame buildings on a statistical basis are as safe as other forms of construction in Canada

Fire resistance measures taken in the Canadian wood frame buildings have produced a stock of buildings that have similar fire casualty record as other forms of construction.

SAFETY REQUIREMENTS IN CODES

Learning Objective:

To understand what Canadian fire safety codes designed to do

Canadian fire codes take a fourfold approach protecting the inhabitants for the effects of fire:

- Through the mandatory use of smoke detectors the occupants are alerted to a fire allowing them time to escape
- All buildings are designed for quick egress in the case of fire. Bedrooms are required to have opening windows of a minimum size to allow escape.
- Breakers on electrical circuits and automatic shut off valves on gas appliances are designed prevent fires from starting
- Wall and floor assemblies are required to have minimum fire ratings typically between one and two hours when they are separating different living units and uses within a building. For instance the separation required between a store and an apartment above would be a two hour fire rating similarly a two hour fire rating is required of the floor separating a garage located in the basement of a home and the living space above.

ALERTING HOME OCCUPANTS

Learning Objective:

To understand that smoke detectors are requires in all houses and CO detectors are recommended

One of the most effective measures introduced into the Canadian code with regards to fire safety is the mandatory requirements for the placement of hardwired smoke detectors in the vicinity of bedrooms. This measure has been so effective because it allows the occupants to escape a fire at an early stage

LIFE SAFETY IN CANADIAN CODES

Learning Objective:

Life safety in buildings is the primary reason that Canadian Building codes were developed

To help ensure life safety in buildings Canadian Fire codes call for multiple pathways for escape in a fire these include both doorways and windows.

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FIRE RESISTANCE AND FLAME SPREAD RATINGS

Learning Objective:

To understand that wall, floor and ceiling assemblies are rated for fire resistance and minimum ratings are required between various occupancies.

- Building codes recognize fire separation ratings for various building wall floor and ceiling assemblies. These fire resistance ratings have been determined by laboratory testing. Descriptions of various assemblies with their fire ratings are given in appendices to the building code.
- Minimum fire ratings for assemblies are called for between different occupancies.
- Interior finish materials must be rated according to their flame spread characteristics

FIRE RESISTANCE RATINGS

Learning Objective:

Wall assemblies are classified according to their fire and sound ratings

To understand that various wood products can be treated with fire retardants

A sample table from a Canadian Building code that gives both the fire and sound ratings for various wall assemblies. Fire ratings are classed according to the time they will protect an occupancy from a fire in an adjacent space in hours and fractions of an hour down to ¼ hour. Assemblies other than those shown in the code tables are allowed if they can be proven to meet the intent of the code.

Structural and finish materials can be treated with fire retardants to enhance their fire resistance. Dimension lumber, manufactured wood products and wood roof shingles are all products that can be treated with fire retardants to enhance their performance. Most fires in homes are caused and or initially fed by contents of the home rather building materials that form part of the home.

SOUND CONTROL

Learning Objective:

To understand sound control measures that are taken in wood frame buildings

- Energy efficiency measures also reduce outside noise penetration because air borne sound will be transmitted through cracks and openings in the building envelope, by air sealing for energy efficiency those pathways are closed for sound transmission.
- Assemblies separating units in multifamily buildings are rated for sound to ensure adequate acoustic separation between units.
- Air borne and impact sound transmission of various assemblies can be compared using STC and IIC ratings. A higher STC rating indicates a greater resistance to sound transmission. An STC of 50 is considered a minimum but in many cases walls between units will be built to higher STC ratings.

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FIRE AND SOUND RESISTANCE

Learning Objective:

To demonstrate the STC and Fire ratings of sample wall and floor and wall assemblies

- Fire rating of 1 ½ hours and an STC rating of 55 for a 38mm x 89mm (2x4) stud insulated wall with double 12mm (1/2") drywall and sound bar on one side.
- The double stud wall with insulation and double 12mm (1/2") drywall on both sides has a 1 2/2 hour fire rating and an STC of 66.
- Ceiling / floor assembly with insulation, sound bar and a double layer of 12mm (1/2") drywall ceiling layer this results in a 1 hour fire rating and an STC of 54 and an IIC of 47

SUMMARY

Learning Objective:

Canadian wood frame construction is based on experience and building science. Heat air and moisture flows are based on the building envelope and the indoor and outdoor environment. Building science principles can be applied to all climates to enable the construction of durable energy efficient wood frame buildings.

Canada has a good record for minimizing fire in wood frame buildings. Wood frame assemblies can have high resistance to fire and sound transmission. Fire retardant coatings are available for a range of wood products.