Participants Guide

Building Science 101

THE OBJECTIVE OF USING BUILDING SCIENCE

Course Outline

Building Science 101

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Module 1: Cold and Temperate Climates

THE OBJECTIVE OF USING BUILDING SCIENCE

Learning Objective:

To understand that the principles of building science can be used to design and construct efficient and healthy buildings

The purpose of this session is to present the principles of building science and to show how their application can be used to produce buildings that are energy efficient, durable, quiet, comfortable and provide a healthier indoor environment.

THE HOUSE AS A SYSTEM

Learning Objective:

To understand that the principles of building science can be used to design and construct efficient and healthy buildings

The purpose of this session is to present the principles of building science and to show how their application can be used to produce buildings that are energy efficient, durable, quiet, comfortable and provide a healthier indoor environment.

HEAT FLOW, AIR FLOW AND MOISTURE FLOW

Learning Objective:

To understand that the house operates as a system meaning that interactions between the building envelope, building occupants, mechanical systems and the external environment affects the home's energy performance, durability and the health of the occupants

For a building to be durable, comfortable and energy efficient it is necessary for the interactions that occur between the occupants, the building envelope, mechanical systems and the outdoor environment be accounted for. The following slides will demonstrate those interactions and how they can be correctly assembled to ensure a successful building.

ELEMENTS OF 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

Building Science 101

HEAT FLOW

Learning Objective:

To understand heat flow through the building envelope.

Heat is transferred through the building envelope by the mechanisms of conduction, convection and radiation. Materials and assemblies that reduce heat transfer by conduction, convection and radiation will retard heat flow, in the winter reducing heating loads and in the summer reducing air conditioning loads. Heat always moves from hot to cold regardless of direction. Heated air on the other hand rises and cooled air drops this is due to the change in density that occurs when air is heated or cooled. The rate of heat loss or gain through the building envelope is determined by

INSULATIONS

Learning Objective:

To acquaint the audience with the terminology used to describe thermal performance of insulations

In North America the typical terms used for describing the performance of insulation materials is in terms of thermal resistance R or RSI. In most of the rest of the world the thermal performance of insulation is expressed in terms of thermal conductance K or U. This series of presentations will give thermal performance of various assemblies in terms of RSI, R and K value.

HEAT LOSS THROUGH WALL ASSEMBLIES

Learning Objective:

To acquaint the audience with ways in which the thermal performance of walls can be affected

The performance of a wall assembly can be affected by:

Thermal bridging in which materials other than insulation in the wall assembly increase the overall conduction of heat through the wall, this can be rectified by reducing the amount of lumber in the wall with advanced framing techniques or using insulated sheathings – a later slide will explain and illustrate this.

Incomplete filling of the cavity: In this case air within the stud cavity can circulate by natural convection bypassing the insulation and causing heat transfer. In a heating climate this will increase the heating load because the air behind the sheathing will drop as it cools down and as it comes into contact with the back of the interior finish it will heat in turn taking heat from the interior of the room. This could also lead to condensation on interior finishes and possible mould growth. This problem can be rectified by complete filling of the stud cavity or by ensuring that the insulation is firmly held against the back side of the wall sheathing so that no air circulation can occur.
Wind washing through batt and blown insulations will increase heat conduction. The insulation must be protected from wind by baffles at attic eaves and by WRB's covering walls

REDUCING HEAT LOSS THROUGH WALL ASSEMBLIES

Learning Objective:

To acquaint the audience with methods for reducing heat loss through wood frame walls

Air circulation can be minimized within wall cavities by:

- Carefully installing fiberglass or mineral wool batt insulation ensuring that it completely fills the wall cavity

- Using a blown fiberglass or blown cellulose fiber insulation system, these blown in behind a nylon mesh and when correctly installed will completely fill the cavity

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TEMPERATURE GRADIENT IN WALLS: COLD CLIMATES

Learning Objective:

To understand that a temperature gradient occurs across wall assemblies when there is a temperature difference between inside and outside and that under the right conditions this could lead to condensation.

The temperature that occurs at a point in a wall assembly is determined by the temperature difference between inside and outside and the thermal resistance of the wall assembly on either side of that point. So in the winter points closer to the inside of the wall will be warmer that those closer to the outside. This becomes important because as air gets colder it's ability to hold water vapour reduces and condensation can form. So in a heating climate in the winter the outer portions of a wall assembly are colder and if warm moist indoor air comes into contact with those surfaces condensation can form potentially leading to rot. In a similar way in hot humid climates in an air conditioned building inside portions of the wall assembly will be cooler and the potential for condensation exists if warm moist outdoor air comes into contact with those surfaces.

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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ROOF INSULATION

Learning Objective:

To acquaint the audience with typical ceiling insulation methods in wood frame construction
Attic and sloped ceiling cavities are typically filled with insulation ranging in value from RSI 4.9 (R 28, K 0.2) to RSI 8.8 (R 50, K 0.11). A ventilation space must be left above the insulation to of at least 75mm (3") to allow for ventilation

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.

AIR LEAKAGE

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.

WIND INDUCED AIR CHANGE

Learning Objective:

To understand how wind drives air through buildings

One of the main causes of air change between the outdoor environment and the interior of a building is wind. Wind forces air into the windward side of the building and causes a negative pressure on the leeward side of the building and at the exterior ceiling drawing indoor out in those locations.

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STACK INDUCED AIR CHANGE

Learning Objective:

To understand the stack effect

The stack effect is caused by the difference in density (weight per unit volume) of warm air and cold air. When a building is heated cold denser (heavier) outdoor air forces its way in at the base of a building driven by gravity. The warmer indoor air rises as it is displaced by the heavier cold air and escapes the upper portions of the building through cracks, holes and service openings. The warm moist air escaping through the building envelope cools as it comes into contact with the wall framing and sheathing which can lead to condensation forming in those areas.

AIR CHANGE CAUSED BY VENTILATION AND COMBUSTION EQUIPMENT

Learning Objective:

To understand how ventilation equipment cause air exchange in buildings

The operation of ventilation equipment causes air to be exchanged between indoors and outdoors. Air exhausted from bathrooms and kitchens must be replaced by outdoor air. In hot humid climates this can result in moisture being deposited both in insulated cavities and inside partition walls.

AIR LEAKAGE PATHS

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.

AIR BARRIERS

Learning Objective:

To understand the concept of an air barrier

An air barrier is formed by systematically air sealing together materials such as drywall, plywood, polyethylene etc and components such as windows and doors to form a continuous barrier to air movement. The air barrier must be made continuous throughout the building envelope. In theory the air barrier can be located on the inside, outside or in the center of the wall, floor or ceiling assembly. If the air barrier is also a vapour barrier it must be located so that it will always be kept above the dew point temperature of the indoor air typically on the interior. The air barrier must be durable enough to last the life of the building or must be accessible for repair. Air barriers have numerous benefits for building energy used, durability and comfort.

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AIR BARRIER MATERIALS

Learning Objective:

To understand what materials can be used as components of an air barrier system

The Canadian building code has defined an air barrier as a system consisting of materials that individually have an air permeance of 0.02L/(s.m2) @ 75 Pa. or less. The slide shows a list of materials that meet this air permeance requirement. Other materials that can form parts of an air barrier system include concrete, OSB, glass, sheet metal and house wrap (when rated as such by the manufacturer).

AIR BARRIER PRODUCTS

Learning Objective:

To understand the air sealing materials and products that are used with polyethylene air / vapour barriers

This slide shows some of the key materials for air sealing polyethylene and airtight drywall air barriers at typical joints and penetrations. A bead of acoustical sealant placed between layers of poly which is then stapled into a wood backing is one of the most common methods of joining two sheets of poly. Contractors sheathing tape is also used for this purpose. Airtight electrical boxes or poly hat box enclosures are manufactured that can be air sealed to the polyethylene with acoustical sealant and staples or tape. Plumbing penetrations and openings between door and window frames and their rough openings are often air sealed with urethane foam. The low density closed cell foam tape is used for air sealing drywall to framing members.

MOISTURE SOURCES

Learning Objective:

To acquaint the audience with moisture sources in housing

Moisture leads to deterioration of a range of building materials by causing rot and mould to grow. Moisture maybe also be contained in building materials such as wood and get built into the wall or roof assembly because not enough time is provide for them to dry. Moisture can enter insulated cavities from either the inside or the outside and is due to air bourne water vapour or precipitation. This slide lists the typical moisture sources that residential buildings are exposed to.

MOISTURE CONTROL METHODS

Learning Objective:

To acquaint the audience with moisture control methods

Exterior moisture entry can be controlled by:

Deflection: rain can be deflected from landing on walls by use of overhangs, projecting sills and flashings

Interior moisture entry can be controlled by:

> Ensuring lumber moisture content is 19% or less before closing in
>
> Spot ventilation: kitchen and bath fans can lower indoor humidity levels in those spaces
>
> Vapour barrier prevents the movement of water vapour by diffusion into insulated cavities leading to condensation
>
> Keeping interior surfaces warm by having an energy efficient building envelope

Building Science 101

CONDENSATION FORMATION

Learning Objective:

To acquaint the audience with the concept of condensation formation by air being cooled

Air contains water vapour, the maximum amount of water vapour that air can hold is determined by the air temperature, as air is cooled it's ability to hold water vapour is decreased. The temperature at which water vapour starts to condense out of air is called the dew point temperature. The dew point temperature of a quantity of air will determined by the amount of water vapour the air contains.
Condensation on building components can be prevented by keeping the building components warm and above the dew point temperature of the indoor air or by reducing the water vapour content of the air by dehumidification or ventilation

FORCES THAT CAUSE WATER MOVEMENT

Learning Objective:

To acquaint the audience with the concept of condensation formation by air being cooled

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VAPOR DIFFUSION CONTROL

Learning Objective:

To acquaint the audience with vapour diffusion control in cold and temperate climates

Vapour diffusion from the building interior into insulated cavities is minimized through the use of low permeance vapour barrier materials. Vapour diffusion provides drying for wood frame wall assemblies when vapour permeable materials are used for exterior sheathings and claddings, WRB's must also be vapour permeable to promote drying

AIR FLOW

Learning Objective:

To acquaint the audience with moisture movement by air flow
Air contains water vapour and as air moves it carries water vapour with it. Warm interior air can contain large amounts of water vapour that when carried into insulated cavities can lead to condensation on cold surfaces such as the back side of the structural sheathing

AIR FLOW & VAPOUR DIFFUSION

Learning Objective:

To acquaint the audience with the relative magnitude of moisture movement by air flow and vapour diffusion
In a heating climate the amount of moisture movement caused by air flow is significantly higher than that caused by vapour diffusion. This slide illustrates the relative magnitude of water passing into a wall cavity over a heating season on the top floor of a two storey house in Ottawa. About 1/3 of a liter of water that would pass through a square meter of drywall where as 10 to 30 liters of water would pass through a

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OPTIMUM RELATIVE HUMIDITY FOR OCCUPANT COMFORT

Learning Objective:

To understand some of the impacts on human health caused by the level of water vapour in the air.

The amount of water vapour contained in air is measured in terms of relative humidity (RH). Relative humidity is a measure of the amount of water vapour contained in air as compared to the maximum amount of water vapour that could be held in the air at that temperature. When air has a 100% relative humidity it is holding the maximum amount of water vapour it can at that temperature and it is said to saturated. As air heats up it can hold more water vapour as as it's temperature goes down it holds less water vapour. The figure presented in the slide shows the relationship between indoor relative humidity and the level of air borne pathogens.

SUMMARY

Applying building science principles allows for the construction of energy efficient, durable, comfortable and healthy buildings

- House must be treated as a system to ensure expected performance
- Airtightness in combination with a distributed ventilation system is critical for energy efficiency, building durability, high indoor air quality and occupant comfort
- A well insulated building envelope reduces energy use, eliminates condensation and mould growth and provides a comfortable indoor environment